Y. FROLOV

WORK AND THE BRAIN

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Honoured Scientist of the R.S.F.S.R.

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PAVLOV'S TEACHING AND ITS APPLICATION TO PROBLEMS OF SCIENTIFIC ORGANISATION OF WORK

FOREIGN LANGUAGES PUBLISHING HOUSE
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Ю. П. ФРОЛОВ

МОЗГ И ТРУД

TRANSLATED FROM THE RUSSIAN BY XENIA DANKO
EDITED BY DAVID A. MYSHNE

CONTENTS

PREFACE

This book deals with the part played by man's nervous system in mental and physical work and the interrelationship between these forms of work in the light of Pavlov's teaching on higher nervous activity. It also deals with the phenomena peculiar to the working of our brain in the face of rapidly developing modern technology. The treatment of this subject will furthermore be accompanied by several practical conclusions which will facilitate the organisation of men's work along rational and hygienic lines in accordance with the findings of modern physiology.

The argument in the text is based on the physiology of the higher parts of the human brain and on Pavlov's theory of two signal systems. Naturally, it has not been our intention to examine in the light of this teaching all the various forms of physical and mental work which are performed in a modern society. Such a task would be beyond us, the more so since we should have been obliged to touch upon the new forms of work appearing today under complex historical conditions at the dawn of the atomic age, with all-round mechanisation in production, at the beginning of man's conquest of the cosmos. The peculiar interrelationship between the human organism and the new environment which man is creating around him will be dealt with in due course.

We have chosen as the main object of our study the most widespread types of mental work, their physiology,

organisation and hygiene. At the same time we thought it essential to touch upon the problems of physical work, physical training, and some forms of art, because in man's march towards communism all these elements must combine harmoniously and supplement each other.

For materialist science work is the most essential condition for the descent of man and the shaping of his consciousness. Work is most intimately connected with everyday practical life and there is nothing incomprehensible, nothing mystical about it. The process of work holds no secrets for the scientist.

In his *Capital* Karl Marx says: "Every element of material wealth that is not the spontaneous produce of nature must invariably owe their existence to a special productive activity, exercised with a definite aim, an activity that appropriates particular nature-given materials to particular human wants. So far therefore as labour is a creator of use-value, is useful labour, it is a necessary condition, independent of all forms of society, for the existence of the human race; it is an eternal nature-imposed necessity, without which there can be no material exchanges between man and nature, and therefore no life."*

Frederick Engels considered work, along with articulate speech, to be the main *condition* of our existence. He expressed it in the following apt formula: "Work has made man." The latest data of modern science fully bear out this idea of the leading role of work in the descent of man.

Inasmuch as this book appeared 35 years ago and is one of the first Soviet popular-science publications in the field of biology, the author has had to revise it from beginning to end, since during this period the face of science itself has undergone radical changes and physiology has extensively developed its methods.

* K. Marx, *Capital*, Vol. I, Moscow 1961, pp. 42-43.

But the main idea running through the book—that there is a most intimate connection between the physiology of the brain and the development of the various forms of work—has preserved its full significance to this day. We firmly believe that a real system of physiology and the organisation of mental work can be based only on the solid foundation of Pavlov's materialist teaching on higher nervous activity, and we are convinced that the great physiologist's teaching itself must—and indeed does—develop parallel with the development of science, industry and agriculture.

CHAPTER ONE

ORGANISM AND ENVIRONMENT

Work and the Sense Organs

If you look at the setting sun from a point on the seashore you will observe the clouds along the horizon gradually fade from bright red into yellow, take on a greenish tinge and finally darken to purple. We have here a good example of the enormous range of colours perceived by our organs of sight as they react to variations in that moving matter which we know under the name of light. The same is true of our other sense organs, those that perceive sounds, smells, touch, etc.

The study of sense organs is closely related to the progress made in the fields of physics, chemistry, biology and technology.

The exterior sense organs—the eyes, ears, organs of smell, taste and touch—maintain a close contact between external reality which exists independently of us, and our inner world, our consciousness, whose material basis is the brain.

Thanks to new discoveries and inventions in mechanics and optics, thanks to the introduction of the latest precise electronic and other devices, we can study much better and more exhaustively not only the processes of nervous excitation in the sense organs, but also the activity of the brain, the central organ which reflects the surrounding world in our consciousness. As science develops, the activity of the brain is becoming clearer and more

comprehensible in all its aspects. Our knowledge of cerebral activity is utilised for improving the material conditions of work and for labour hygiene.

The study of the structure of the sense organs and the mechanism of our cerebral activity facilitates, among other things, the solution of a number of problems pertaining to the organisation of mental work and mental hygiene.

Take, for example, the organ of vision. Like the other sense organs of animals, it arose in the lowest organisms. In those organisms it existed in the form of transparent crystals in the skin, which by refraction focussed light rays in one point. Special sensory endings developed at this point to receive the light and were connected with the primary receptive cells (the eyes of some sea animals, for instance, medusae, are constructed in this way).

In the process of evolution the neuro-cellular apparatus retreated, as it were, into the body while the refracting structures remained on the surface preserving direct connection with the outside world and with the radiation energy coming from the sun. Part of the nerve cells transmitting the light stimuli also remained on the surface. These have become the first stage, the first step on the road to the centre, the brain, to which all external signals are transmitted.

Thus the eye of the higher animals and of man consists of a simple optic apparatus—a transparent lens which concentrates in one point the rays of light from external objects and reduces the image to the minimum—and another, more complex, part transforming the perception of light into a special nervous process that reaches the cerebral centres and produces the sensation of light, darkness, colour, brightness, etc. The energy of light is perceived by special apparatus in the retina—the so-called rods and cones. The rods enable us to see in the dusk when the light is feeble and we cannot distinguish colours. Animals with nocturnal habits have excellent vision but they

cannot distinguish colours and use only the form of objects and intensity of illumination to find their way about. The ability to distinguish colours lies in the cones.

The eyes develop gradually: in the embryo they are formed from the optic vesicles which grow from the forebrain; after birth the eyes retain their connection with the brain through the optic nerve. The inner membrane of the eye—the retina—has a complex structure resembling that of the cortex. Like this, the highest, part of the brain, it consists of several layers of nerve cells of different shapes.

In order to ensure correct reflection of external objects on the retina we are dependent also on the activity of the six pairs of eye muscles which turn the eyeball. Visual perception has been connected with motion from the very beginning. The muscles moving the eyeball ensure the correct passage of the central beam of light rays along the optic axis, and direct these rays to the most sensitive spot on the retina, the so-called *macula lutea* or yellow spot, where the object is reflected. The muscles of the eye, therefore, make it possible for us to orient ourselves in the world around us.

The other sense organs also depend on both cerebral and muscular activity, as the muscles bring them to bear on various objects. The sense organs are not only "the gates opening on to the world" but also a means of mastering this world. When we fix an object with our eyes we take the first step towards acquiring a knowledge of it.

Further we shall see that every muscle, and not only the eye muscles, is a kind of a sense organ; muscles contain nerve endings from which constant streams of impulses carry to the brain information of their position at each given moment and, consequently, of the position of the object fixed.

Certain errors and illusions are inherent in our vision; these are observed as regards both colours and lines. Long

parallel lines crossed by short dashes seem to us non-parallel. This optical illusion is due to the fact that the eye moved by the muscles follows the crossing dashes, which distorts the perception of the long parallel lines. It is not the peripheral organ—the eye—but the cerebral centres where the perception arises as a result of the signals coming from the eye muscles that are responsible for the illusion. However, all such errors are corrected with the aid of other sense organs, for instance, touch, and we finally get a correct picture of the surrounding world. But, if we do not check on the work of our eyes with measuring devices, if we do not ascertain the direction of various lines with compasses, we may make serious mistakes.

Illusions in the sphere of colour vision can be the cause of confusion and even of accidents, for example, in all forms of transport work. If one looks fixedly at a red circle on a grey background, the circle will appear green, that is to say, it will take on a complementary colour. This is the result chiefly of nervous induction—the consequence of the antagonistic process operating in the brain. All our life, all our visual perceptions abound in contrasts, yet man can be freed from these optical illusions by training and supervision.

Physiology, together with labour hygiene, is concerned with reducing to the minimum the number of mistakes in work, for instance at night, caused by fatigue of both the eye and the brain.

The hygiene of vision, so important for any type of work and especially for mental work, requires that the source of light should be screened by a special shade, preferably green, directing the light to the surface of the table and leaving the eyes in the shade. Good results are obtained with luminescent lamps. This is an effective means of preventing fatigue of the eyes, which inevitably develops in everyday life and at work if the work place

is inefficiently equipped, especially if the work involves small objects, reading, writing, etc.

Various devices which extend the range of our sense organs are of great assistance in our perception of natural phenomena.

The branch of physics, known as optics, and technology, which expands man's working possibilities, also extend our knowledge of the outside world.

There is a large variety of technical (optical) devices which render our visual perceptions more precise. Spectacles are a means for correcting defects in the refraction of light rays in the crystalline lens, the defects being due to extreme contraction or relaxation of the muscles controlling the lens. Other popular devices are binoculars, range finders and telescopes. "Spectacles" enabling man to perceive long-wave infra-red rays and, consequently, see in the dark at distances of up to several kilometres are a recent invention. In addition to the microscopes and telescopes of different makes, the technical appliances that assist our eyes include radio and TV receiving sets, thermoelements, roentgen apparatus, the device for studying gamma rays, and others, capable of receiving electromagnetic waves of different lengths (Fig. 1). All such devices extend man's cognitive abilities and are based on the achievements of technology, electronics in particular. In our diagram they are not distributed haphazardly, but are ranged in accordance with the length of electromagnetic waves. Each of them makes possible the investigation of definite wavelengths. All the various waves can be arranged in a series of octaves, like the piano or accordion keyboards, consisting of regularly repeated series of seven notes (c, d, e, etc.).

Our eye can perceive only one of the many octaves of electromagnetic waves. Yet this single range includes the wealth of our visual perceptions from red to purple. This relatively poor set of colour hues suffices the artists in painting their pictures and carpet-weavers in making

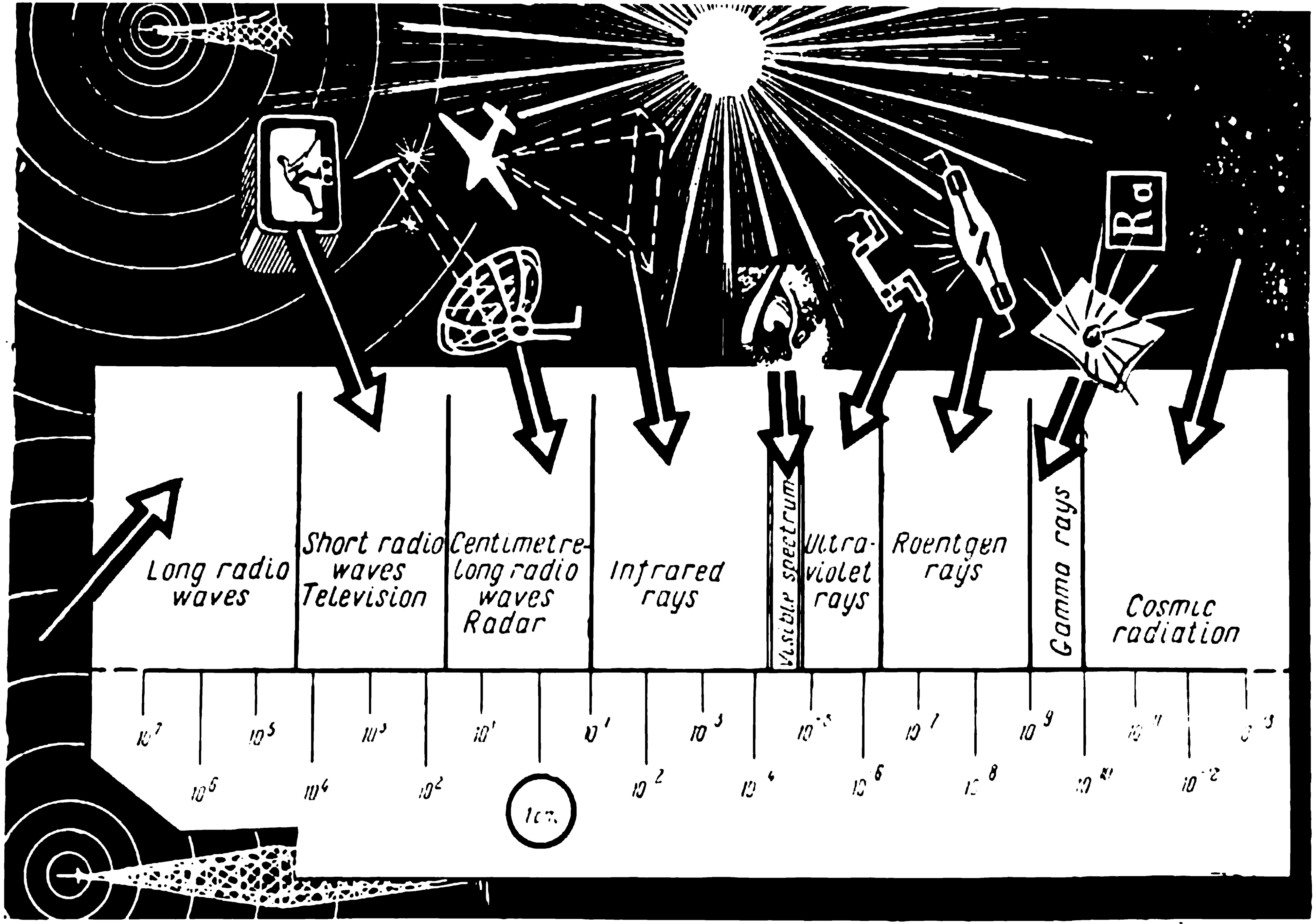

Fig. 1. Scale of electromagnetic oscillations (waves). Perception with the naked eye and with the aid of various measuring devices

magnificent rugs and tapestries. In order to produce the impression of vivid colours and receding planes that are found in nature, they utilise the colour contrasts we have mentioned and the laws of line perspective creating the illusion of receding objects, as well as the effect of a picture which stretches away to the background.

As time goes on, modern technology increasingly extends our natural abilities, broadening the scope of our organ of vision and enabling us to see what has hitherto been concealed from us.

Human auditory sensitivity is based on the wonderfully constructed and extremely fine sound receiver, the cochlea, in the inner ear, to which thousands of live "strings" are attached, and which, like the visual receptors, are connected by nerve fibres with the auditory centres of the brain. Our faculties for auditory perception are extended by modern acoustic devices capable of receiving super-sounds, so that instead of seven or eight octaves we can now "perceive" more than twenty.

Electronics has made it possible today to transform almost all forms of moving matter known to us into other forms which are easier to measure and compare, viz., into electromagnetic waves. Electronic amplifying and measuring instruments (cathode tubes and semiconductors) help us to study the activity of sense organs and muscles. Medicine and labour physiology have greatly benefited from the application of new technical achievements (Fig. 2).

A sense organ is not isolated within its own sphere, but the activity of each is intimately connected with the changes taking place in the environment. The sensation caused by, say, light, sound or smell, does not become more intense in a direct ratio with the increase in intensity of the light, sound or smell. The activity of the sense organs proceeds in keeping with a certain regularity governed by the law known as the law of logarithms: if the intensity of the external stimulation grows in a geometric

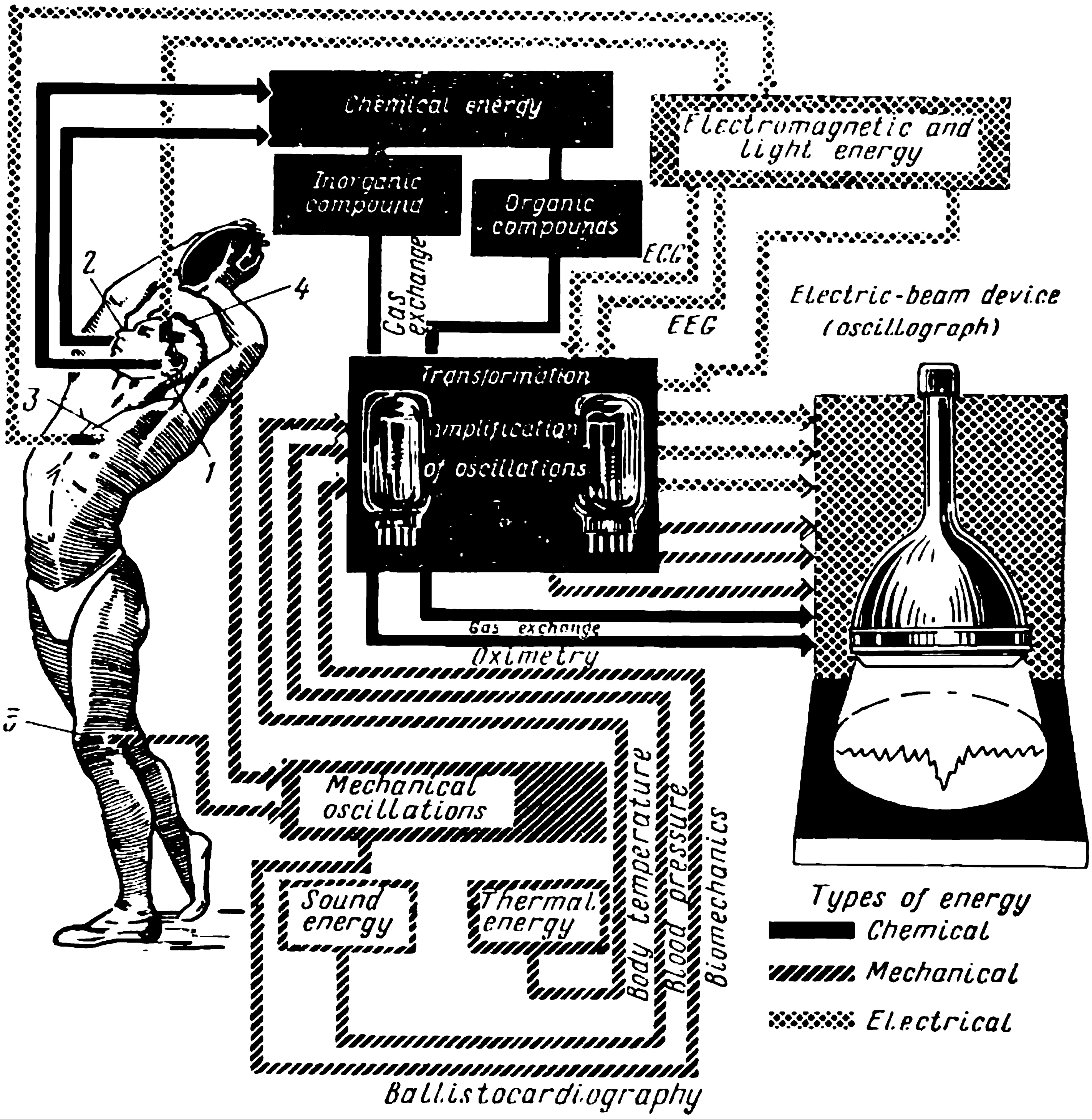

Fig. 2. Studying the functions of the human organism with up-to-date electronic devices:
1—photoelectric determination of haemoglobin; 2—determination of gas exchange; 3—electrocardiogram; 4—encephalogram; 5—skin temperature

progression, the sensations increase in arithmetic progression. For example, if one candle is lit in a dark room and then another, one feels that it has become much lighter, but if two candles are burning and a third is lit, one feels but an insignificant increase in the brightness of the room.

If, finally, ninety-nine candles are burning and one more is lit, we shall not be conscious of any increase in the intensity of lighting, although this hundredth candle is burning with an intensity equal to that of the first or second candle. This law obtains not only in the activity of the sense organs but in that of the brain as well.

The sense organs of animals prove their superiority over technical devices by the ease with which they are able to adapt themselves to their environment. Adaptation is closely connected with the process of evolution, the historical development of the adaptive change in animals under the influence of their conditions of existence. The central nervous system plays an important part in the processes of adaptation.

But there are certain limits to the excitability of the nervous centres. The intensity of our sensations cannot grow indefinitely: at a certain stage fatigue sets in. This may cause errors in perception, and sometimes eye diseases or diseases of the brain. That is why various preventive signals have been installed along railway lines, roads and in factories to prevent accidents in cases of fatigue. But if the signals are too numerous or too bright they may prove less effective. In trying to focus the attention on some object it is not enough to make the stimulus sufficiently strong, but it is also necessary to consider the other properties of sensation; the signal must be able to attract and hold the worker's attention.

Man's Adaptability to His Environment and the Changes Produced in the Latter by His Work

Speaking of the relation between an organism and its environment back in 1861, Ivan Sechenov, the father of Russian physiology, said that an organism without an environment supporting its existence was unthinkable.

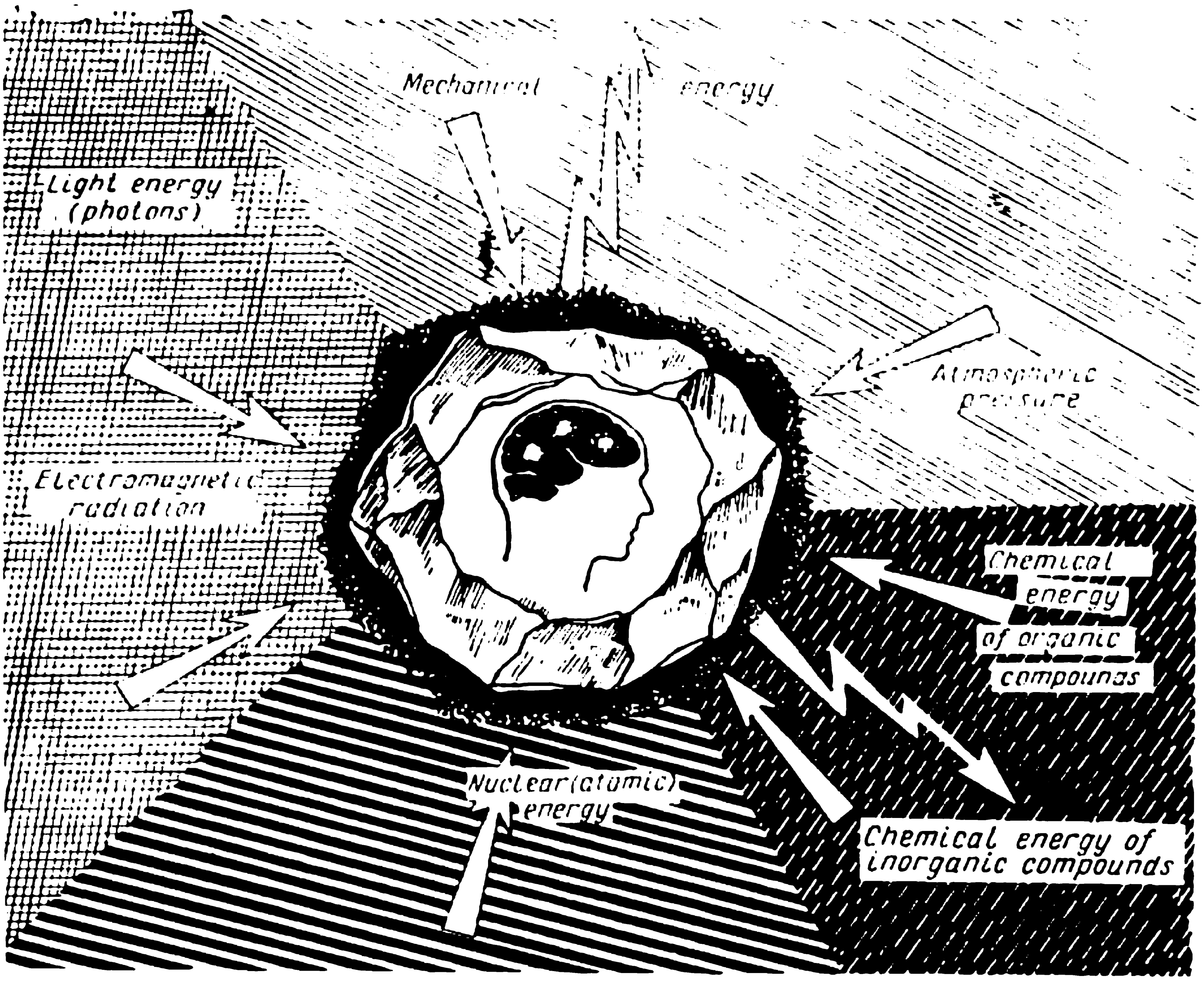

Fig. 3. Interaction of organism and environment. Arrows indicate energy exchange

The scientific definition of organism must, therefore, include the environment which influences it (Fig. 3).

The world around us provides ample proof of this profound thought. Numerous examples can be given, to say nothing of such well-known facts as that, in order to live, an organism must receive oxygen and food from its environment.

Everybody knows that the air we breathe and the atmosphere in which we live exerts a tremendous pressure on our bodies. This pressure, however, does not flatten

us but on the contrary, facilitates movement by keeping our bones in their joints. We do not feel the weight of the atmosphere because the pressure is the same within each organ and each cell.

A fall in the atmospheric pressure may disturb many of the physiological functions, with consequent weakness, and if no measures are taken, loss of consciousness.

And yet man can adapt himself to changes in the pressure exerted on his body within broad limits. Provided with aqualungs and a supply of oxygen, modern divers need no diving suit to go down to a depth of 40-50 metres where they stay for nearly an hour, move freely over the bottom of the sea, look for sunken cargoes or catch fish. There are pearl fishers who dive to great depths even without any technical appliances, although to be sure, they do not stay there long.

Much the same can be said about the adaptability of living beings, including man, to cold, wind and humidity.

Microbiological discoveries have shown that in addition to inanimate nature we are surrounded by another important medium—the biosphere. This medium consists of countless minute beings invisible to the naked eye, some of them useful, others harmful to life. This biological environment is even more subject to change than is the climate. The organism can in some measure adapt itself to this environment as well. Scientists have noticed that when animals are infected with anthrax under experimental conditions not all of them contract the disease and die. The weakest and least adapted perish, while the strong emerge victorious from the life-and-death struggle with the dangerous microbe.

It has been furthermore established that in the struggle against the causative agents the organism gradually acquires immunity to many infections. Hardening one's body, physical exercises and sport, rational organisation of our daily work, rest and diet go a long way towards

strengthening and enhancing the adaptability of the organism.

Adaptation to various mechanical, thermal, atmospheric and other influences is effected by the nervous system.

The clearest indication that an organism has adapted itself to a new environment is the constancy of its main physiological indices: the heart and respiratory rates, blood pressure, body temperature, etc. An organism stably retains these vital constants, using in each particular instance its enormous reserves of strength. When the need arises, it can change these constants within certain limits.

Higher animals are known to possess a constant body temperature. As soon as the environmental temperature rises, the organism must urgently reduce the production of heat and increase its loss. Some mammals, for instance cats, achieve this by limiting their muscular movements, others do it through perspiration. Sweat evaporates from the surface of the body and carries off with it part of the heat, thus preventing overheating. The animals that have no sweat glands, for example, dogs, open their mouths and stick out their tongues with the blood vessels filled with blood. Instead of sweat, the cooling is effected by abundant salivation.

The reactions acquired in the course of life (conditioned reflexes) form the basis of our gradual adaptation to all kinds of changing external conditions, such as cold, heat, microbes, solar radiation, and so on. This property of adaptation to sharp changes in the environment makes possible the acclimatisation of animals and man. Some organisms have spread all over the globe because they have gradually been able to adapt themselves to the environment.

The acclimatisation of man and his capacity to adapt himself to constant changes in his environment show that our organism acts as an integral whole, obeying a central controlling organ—the central nervous system.

The organism's connections with the environment are multiform. Besides its reactions to the atmospheric pressure, the climatic factors and biological environment, our organism has to respond to the action of different types of energy—chemical (food), mechanical (including the atmospheric pressure that has been mentioned), thermal, electromagnetic, and, lastly, the action of cosmic radiation. Each of these factors evokes definite reactions in our organs, which derive benefit from some and resist the harmful influence of others. Too bright light, for instance, could harm the organism if it did not protect itself through the adaptive narrowing of the pupil of the eye.

However great our capacity to respond to external changes may be, modern society cannot rely wholly on these biological, inborn, means of defence and must enlist the assistance of safety engineering.

Armed with up-to-date knowledge, man has set himself the practical task of not only adapting himself to his environment in the best possible way, but of reshaping the environment itself in accordance with the needs of society.

Substances that have never existed in nature have been produced in the laboratory. Thus man enriches the globe with his handiwork and takes part, as it were, in the constant "creation of the world".

In addition to common natural sources of heat, physicists have obtained temperatures of the order of a million degrees; this does not mean that some day man will be able to live in such temperatures, but it goes without saying that the discovery of thermonuclear reactions has broadened our knowledge of the nature of heat, that we shall be able to use this knowledge for analysing life's phenomena and that, finally, it will benefit our health.

We see that the interaction of man and nature proceeds in two equally important directions: the adaptation of the organism to the environment (this is the ob-

ject of classical general physiology) and the remaking of nature by the collective efforts of human society.

The interaction between the human organism and its environment can be explained correctly by the social character of work and collective methods of reshaping man's environment. We are speaking of what Marx called the regulation and control of the material reactions between man and nature in the process of work, when, as the founder of dialectical materialism put it, "he [man—*Y.F.*] opposes himself to nature as one of her own forces".*

In this case it is, consequently, not a mere interaction between animate and inanimate bodies, but extremely complex relations, the dialectical development of animate and inanimate nature, including man's planned utilisation of natural forces for his own benefit as observed in modern socialist society.

The ways in which we influence our environment are most varied and the changes wrought by man in surrounding nature are very great. The changes taking place in the brain, the organ that reflects the whole of the surrounding world, are all the greater and more distinctive in their quality.

Engels stressed the fact that the thought processes and reasoning powers of man develop as a factor of the communal work carried out by man in his efforts to act upon nature. It follows from this that the laws of physiology by themselves will not furnish an adequate explanation of the new levels which have been attained in the communal organisation of labour. The physiology of labour requires the help of *social sciences*—philosophy and economics. And it is at this point that one can see the full significance of dialectical and historical materialism for the success of objective research work.

Man *is not only a biological but also a social* being. This means that the norms of human behaviour are sub-

* K. Marx, *Capital*, Vol. I, Moscow 1961, p. 177.

ject to modification by the circumstances in which man may find himself in any particular historical period.

Primitive man was unable to exert any noticeable influence on nature. But now that human society has attained high labour productivity, traces of man's influence on nature are in evidence all over the earth and are actually ineffaceable. In the process of his work man changes nature at the same time changing and developing himself.

Pavlovian Physiology as Related to Studying Work and Mental Hygiene

Although the great physiologist did not make work the object of his study he, nevertheless, laid a firm physiological foundation for a correct understanding of the aims and methods of research in this field.

The modern materialist teaching on the work of the brain, for which we are indebted to Pavlov, must, like other sciences in the U.S.S.R., advance the interests of the new, socialist society, where the leading role is played by all forms of constructive work. The achievements of physiology extend to other branches of science—biology, agriculture, medicine and pedagogics. This is especially true of Pavlov's teachings on higher nervous activity as the material basis of consciousness and on its role in man's behaviour at work.

Each science, including the physiology of work, has its specific aims which require a specific approach and definite methods. Pavlov's theory offers great possibilities for research into the behaviour of human beings at work, as well as for improving the working and living conditions. Our latest knowledge of higher nervous activity makes possible the introduction of new, progressive forms of work, and of labour-saving devices to utilise the achievements of up-to-date technology, and above all, electronics. Pavlov's teaching is inseparably connected with the

general advances of science and is an integral part of Soviet humanism.

In one of his public speeches Pavlov said: "Natural science with its practical application—technology—is man's chief force. From the immeasurably rich nature man takes all he needs and all that benefits and pleases him. But that is not all; what are all these treasures to me if I am constantly ill and weak? To use the treasures of nature, to enjoy them, I must be healthy, strong and wise.

"We are the highest product of terrestrial nature, its most complex and finest system. To preserve this system intact and unharmed, we must know how it functions. It is at this point that we have an important part to play, along with our branch of natural science—physiology—which permits us to have this knowledge. Physiology will teach us increasingly better and more completely to work, rest, eat, etc., correctly, i.e., usefully and agreeably. Nor is that all: it will teach us to think, feel and act correctly. That, too, is part of our aim."*

The foundations for the Soviet physiology of work were laid at the time Pavlov was living and working. Now that the material basis for the building of communist society has been created this science has made considerable progress. Soviet physiology aims to study objectively the functioning of the organism as a whole, as well as of its individual organs in close relation to the surrounding conditions (general, communal, industrial, school and other branches of hygiene). Together with biochemistry and biophysics, it studies the influence of living conditions on the organism so that we may change them for the good of the working people who are the only producers of all material and cultural values. Jointly with other sciences Soviet physiology also studies the evolution of human

* Pavlov's Speech at the Reception for the Delegates to the 15th International Physiological Congress in 1935. Record edited by B. Zbarsky, Biomedgiz, 1936, p. 139.

nature in the process of historical development of man's higher nervous activity, labour in particular. It aims to discover the conditions favouring all-round utilisation of the inexhaustible resources of the human brain.

To live, i.e., to have food, clothes and shelter, and make the means and instruments of production, man must work day in and day out. Everybody knows this. But Soviet physiologists were the first to prove that work, both mental and physical, is not only a prime necessity but even the main requirement of the human organism, ensuring its health and an all-round development of all its organs and functions.

In this brief outline we cannot touch upon all that modern physiology based on Pavlov's materialist teaching on the brain deals with, and must limit ourselves to questions pertaining to the problem of mental and physical work. As we go on we shall endeavour to show the importance of the connection between theory and practice in the field of hygiene of work and labour protection.

The successful fulfilment of the Seven-Year Plan of the Economic Development of the U.S.S.R. has altered our ideas of the ways and means, as well as the scope of rationalising labour and above all of completely mechanising it, especially since the initiative comes not only from above but also from below, from the working masses themselves.

Of the achievements which are important for the national economy of the Soviet Union and for the attainment of new objectives in the physiology and hygiene of work in particular, we shall mention the following: the introduction of the seven-hour (subsequently, six-hour) working day, strict control of the work and rest of the people labouring under special conditions, annual paid holidays, obligatory lunch breaks, shorter (by two hours) working days on Saturdays and on days preceding holidays, shorter working day for teen-agers, introduction of the six-hour working day in mines, longer pre- and post-natal

leaves. We must also mention the measures which, although not dealing directly with production, are nevertheless very important for improving labour hygiene, namely, the ample educational opportunities, including higher education, the system of education by correspondence, extensive housing construction, extension of the network of medical institutions and improvement of the health services, development of physical culture and sports, participation of the working people in managing all branches of production, encouragement of amateur art activities, etc. All these measures show the Communist Party's and the Soviet Government's concern for the upbringing of a healthy and optimistic generation during the years of transition to communist society.

CHAPTER TWO

GENERAL PHYSIOLOGY AND KINESIOLOGY

The Physiology of Natural Movements and of Physical Culture Activities as an Introduction to the Study of Work

Any work, especially physical work and sport, involves muscular activity. Historically the study of work began with the analysis of simple physical work and sport. The problem of rationalising the work processes in the light of physiology should also be approached from the analysis of simple natural movements such as walking, running and other cyclic reactions. With these movements the same effort is repeated over and over again, and a certain group of muscles is contracted and relaxed.

More complex movements, such as work at a bench, driving the car, playing the violin, riding the bicycle and other similar work efforts, differ from the natural movements mainly in that the object of work—the bench, the car, the bicycle, the violin—has been invented by man, the movements of the working person corresponding to the operation of the instruments of production and combining with the latter to produce a single complex.

In this case the muscular movements are broken down into parts, while some of working organs are switched off and are resting—this being achieved by redistribution of excitation and inhibition in the nervous system. The decisive role here is played by the signals coming from

the vestibular apparatus in the ear and from muscle receptors (organs of muscle sensitivity). Their stimulation produces a reflex influence on the cardiovascular and respiratory systems, metabolism and other functions of the organism. Natural movements such as walking, running and the like, are distinguished for their high degree of neuromuscular coordination. They are mastered quickly and at a very early age. These movements are mostly cyclic, i.e., constitute a series of similar contractions of muscles repeated a number of times.

Shifting of the body weight from one leg to the other is the characteristic feature of human locomotion (Fig. 4). The free leg is thrown forward, covering a distance that depends on the walking pace. The difference between walking and running consists in the rate of alternating the individual phases which make up the cycle of movements of the walking or running man (Fig. 5).

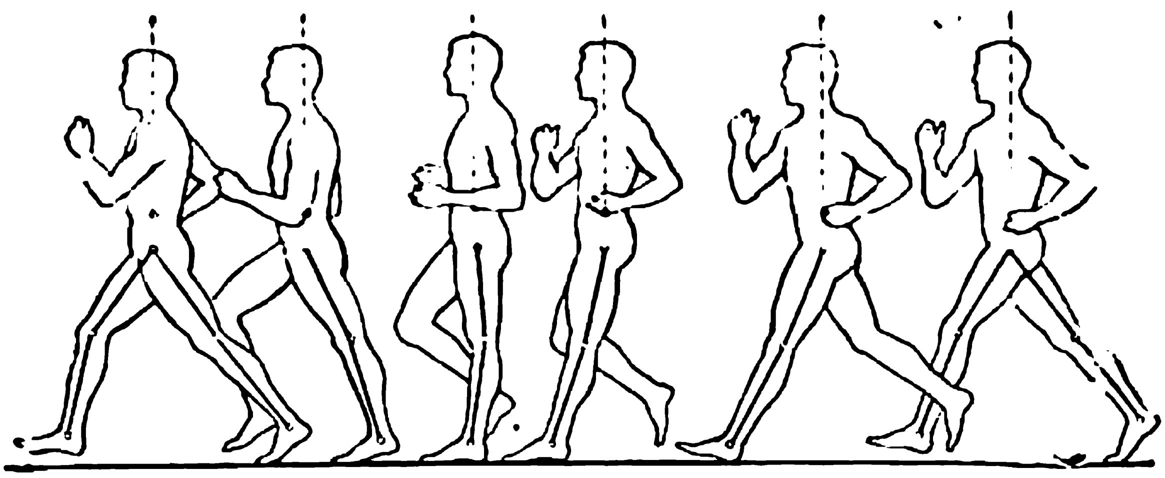

Fig. 4. Cyclogram of walking

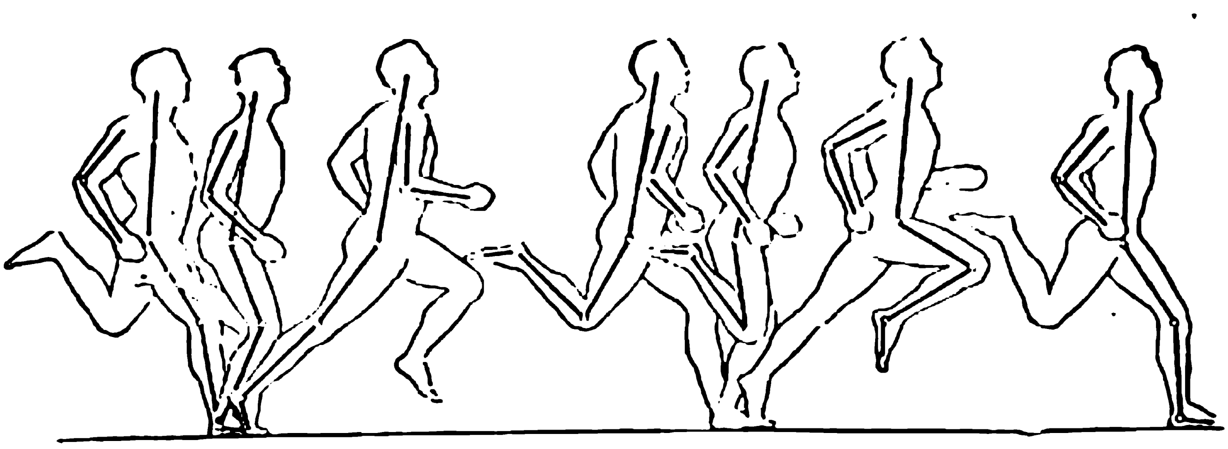

Fig. 5. Cyclogram of running

The bony, muscular and nervous apparatus which take part in walking and other movements are finely differentiated and well adapted to assist each other. Dozens of muscles participate in walking, each performing its own function: they not only move the walking man forward, but prevent him from falling by changing the body's centre of gravity.

The centre of man's gravity in an upright posture is rather high, in the region of lumbar vertebrae, this being one of the characteristics that distinguish man from most of the mammals, including the apes which always support themselves by the arms. A perpendicular dropped from the centre of gravity of the human body falls to the area formed by the line joining the toes and heels of both feet.

The body of a walking man is in unstable equilibrium. This, however, does not hinder us from keeping our balance even in most complicated athletic movements, since the centre of gravity constantly shifts in accordance with our movements.

Physiologically, walking is alternating disturbance and restoration of equilibrium as a result of the shifting of legs. This also applies to certain types of athletic and working movements, the leading role in the latter being played by the hand coupled with an instrument of production.

The differences in the shifting of the legs and in the nature of equilibrium, depending on the different manners of shifting the centre of gravity, determine the gait of different people.

Any normal human being learns to walk, i.e., lift and move his legs, at the same time shifting the weight of his body from one leg to the other, in early childhood. Besides the nervous centres in the spinal cord, which directly regulate the contraction of the leg muscles, an important role in walking is played by the highest part

of the central nervous system—the cerebral cortex where all movements are coordinated.

Physiologically, to learn to do something, for instance, to ski or throw the javelin, means to establish a coordination between the individual working organs through the nervous system.

Although walking in the upright posture is an inherited characteristic of mankind, the process of teaching a child to stand upright and to walk takes considerable time. In this man differs from most of the birds and mammals whose young can stand on their legs and walk by themselves immediately they are born. The running reflex in man is not inherent but is acquired, albeit easily and at a very early age.

The reflexes whose paths in the nervous system are prepared but must be trained are called natural or inborn. They differ substantially from acquired reflexes which demand longer training, as for example, learning to operate a lathe or some other machine.

Like other inborn conditioned reflexes, the walking reflex can be extinguished through lack of training: a person who owing to illness or wounds has long been bedridden may "forget how to walk", but this state does not last long, and the convalescent quickly regains the habit of coordinating movements of walking.

Walking is mastered more quickly and the reflex is stabler than is the case with acquired reflexes; it is preserved unchanged longer during the process of ageing.

And yet the walking movements must be attended to not only in childhood. The style of walking used by athletes needs constant practice; lack of training leads to deterioration of the style.

Walking, as has already been mentioned, depends on precise interaction of the principal joints and muscles of the legs and feet. Each muscle has its antagonist. The strong gluteal muscles, for example, are antagonists of the flexor of the thigh. The same holds good for the mus-

cles of the knee joint, its extensor being the *quadriceps femoris* and antagonists, the muscles on the posterior surface of the thigh. The foot is extended by the anterior muscles of the shank and flexed by its posterior and lateral muscles.

The coordinating function of the nervous apparatus in regulating walking is manifested in simultaneous excitation of the flexor muscles of one leg and the extensor muscles of the other.

Walking is not only an alternate contraction and relaxation of muscles as a result of the excitation and inhibition of corresponding nervous centres—it is a complex process in which an important role is played by reflexes coming from the internal organs which cater to walking. The source of these reflexes is the contracting muscle itself and its nervous apparatus which transmit information to the nervous system on the state of a certain muscle and that of its antagonists at any given moment. Like many other movements, walking is often automatic.

The gait of every individual has its peculiarities. At the same time it has been established that the gait of a normal person is rhythmic, its phases alternating with almost mathematical precision. That is why it is easy to record them, as has first been done by Marey.

The leg movements obey the laws of a swinging pendulum, the point of attachment of this live "pendulum" being the greater trochanter in the hip joint of the moving leg. This explains the vertical displacement of the centre of gravity in walking. When the "pendulum" passes through the lowest point the centre of gravity lies higher. The vertical displacement amounts to 4 cm. It is only at this point that the muscles begin pushing the body forward, propelling it in the most important direction, i.e., the horizontal. The moment when the body rests on two supports corresponds to the lowest position of the

body's centre of gravity as regards the earth. This moment lasts a mere 0.1 sec.

In walking the arms move in directions opposite to those of the legs: when the right leg moves forward, the right arm swings backwards and vice versa. The nervous centres regulating the arm movements in walking have close reciprocal connections with the nerves regulating the work of the leg muscles. This also makes for maintaining balance and harmony of movements.

Even when standing upright, the body's centre of gravity shows a constant slight oscillation around the mean position. To gain an idea of the complexity of the act of walking, especially under the difficult conditions that are very often encountered in life, let us analyse the movements of a man who is walking on smooth ice with the aid of a stick, or a mountain-climber with an ice-axe. When the sole of the foot touches ice the friction is much weaker than it is in walking on the ground. Consequently, there is more chance of losing one's balance, i.e., of moving the centre of gravity outside the area limited by the toes and heels of the feet. If the man uses a stick for maintaining balance he must lean on it each time precisely at the moment when one leg acts as a pendulum and the other as a support. Watching the stick press against the ground as an almost involuntary act will show the phase in walking where the body rests on only one leg and is in the most precarious position. This moment lasts 0.35 sec.

If a man carries a burden, the distribution of its weight on his back considerably changes the location of the centre of gravity, which affects the dynamics of his locomotion. A man carrying a load usually makes shorter steps. The time of rest increases, while the pendulous swing of the leg is shorter.

Other, more complicated types of movement, some of which are used in work, for example, working the treadle

of a grindstone, as well as various athletic movements (skiing, skating, cycling, etc.) have developed from that simple system of movement—walking.

When the number of steps per minute exceeds 190, the walk develops into running. It is no longer possible to accelerate the pace and the moment when both feet touch the ground (0.1 sec) is superseded by a leap, a "flight", when both feet are off the ground.

Can people be made to walk with steps of a certain length and at a set pace, reducing to the minimum the individual peculiarities of their gaits, which interfere with "style" walking? Experience shows that it is quite possible to make the aforesaid walking phases very distinct and that natural movements can be trained. In "style" walking an athlete will walk at a definite pace and a set rhythm, and will not readily tire because he knows how to avoid unnecessary movements. At the same time he will move more skilfully and will, therefore, be capable of enduring the strain longer than a walker who has learnt to walk just according to his own fancy, now mincing his steps, now making enormous paces, swaying from right to left, and swinging his arms or shrugging his shoulders. Each day of systematic training makes for precision in neuromuscular coordinations, economy in energy and beauty of motion.

Working muscles need more nutriment and oxygen. This increases the load on the cardiovascular and respiratory systems which are interconnected and are under the constant control of the nervous system. Exercise and training improve and strengthen cardiac activity, develop the respiratory system, make more precise the nervous regulation, which plays a decisive role in developing the physical potentialities of a trained person.

This applies in equal measure to walking and all types of sport and work.

Studying and Measuring Muscular Work

A few words about the energy characteristics of walking as an exercise which, in addition to its direct purpose, offers excellent recreation after mental work. The distance covered per unit of time, for example, one minute, can be taken as the unit of physiological work done in walking on level ground.

Any increase in the effort demanded in walking has a much sharper effect on the organism than that brought about by a simple lengthening of the operation, i.e., an increase in the number of hours spent in walking. This applies to many other types of natural and artificial movements, as well as to movements performed at work.

There is a fairly constant correlation between the speed of the movements and the maximal duration of walking. The dependence between the speed of the movements and the distance is evident from the world records in walking and running. A long distance runner runs slower (5-6 m/sec) than a middle distance runner (7-8 m/sec); a sprinter running 100 m shows the greatest speed—9.8 m/sec. But in marathon running (over a distance of 42.1 kilometres) the record speed is 4.71 m/sec and this in no way detracts from the merit of these records.

All the above types of muscular activity require the expenditure of certain amounts of energy, manifested in mechanical work.

In most cases the expenditure of energy is proportional to the speed, or the distance covered in a unit of time, i.e., the power of work.

Modern physiology of work and exercise attaches particular importance to measuring the gas exchange. Since all types of energy are transformed into heat, the expenditure of energy by a working organism is measured in heat units, which are called calories.

It is not always possible to measure the expenditure of energy directly, for which reason indirect calorimetry

is often used, i.e., the gas exchange is studied and then expressed in terms of calories.

To study the gas exchange, a rubber mask with a mouthpiece (Fig. 6) is put on the lower part of the face.

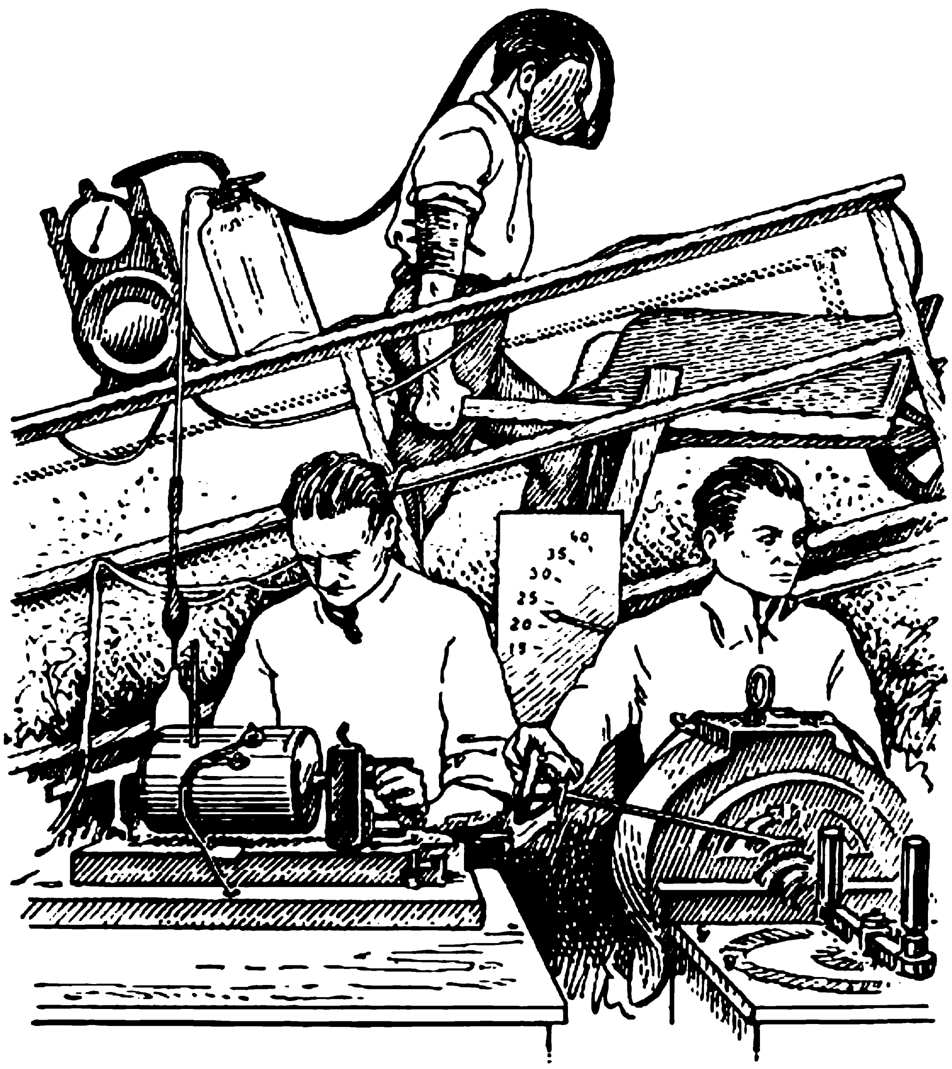

Fig. 6. Studying gas exchange of man during physical work (wheelbarrowing a load up an inclined plane). Two investigators in foreground

The nose is clamped with a special device. The mask has two valves—inspiratory and expiratory. During inhalation the expiratory valve is closed and vice versa. Through the expiratory valve the air from the lungs goes to a big rubber bag (Douglas bag), where its volume can be measured and the composition studied.

Suppose that in the course of a five-minute experiment a man exhales 150 litres of air, that is, 30 litres of air

pass through his lungs per minute. Considering that normally an average of seven litres per minute passes through the lungs of a person resting in a recumbent position, we find that movement at a set pace has increased the ventilation of the lungs 4-4.5 times. The increase in ventilation was due to two factors: number of respirations per minute (24 instead of 16) and the volume of air inhaled (1,100 ml instead of 500). The latter factor is the more important of the two, especially in cases of well-trained subjects.

Atmospheric air contains about 21 per cent oxygen but the expired air has only 16 per cent. This means that nearly 1,500 ml of oxygen is consumed per minute and that the organism retains 50 ml of oxygen from every litre of air that passes through the lungs.

The oxygen taken in by the organism is used to oxidise the intermediate products (particularly lactic acid) which are formed in the body as a result of the work it performs. There are also many other complex intermediate processes connected with phosphorus metabolism in the body.

The series of transformations results in production of energy which is expended on mechanical work and is finally liberated in the form of heat. If we know the quantity of heat obtained (in calories) and take into account the *mechanical equivalent* of heat, we can easily calculate the amount of energy expended and the amount of work done.

It has been found that one litre of oxygen consumed by an adult corresponds on the average to 4.5 large calories of heat in the body. The body of a man walking at a moderate pace along a smooth road produces 6.75 large calories of heat per minute, or 337.5 large calories in 50 minutes. Since the efficiency equals about 30 per cent, the figure is 112.5 large calories per hour, or rather per 50 minutes, for the remaining 10 minutes are usually spent on rest. Thus 112.5 large calories is the expenditure of

energy in an hour of walking under optimum conditions.

Let us calculate the amount of effective work performed in walking (in kg/m). The mechanical equivalent of heat is 425. One litre of consumed oxygen corresponds to 4.5 large calories of heat. The mechanical equivalent of one litre of oxygen is equal to $425 \times 4.5 = 1.765$ kg/m. Under the aforesaid conditions the consumption of oxygen per minute equalled 1,500 ml, consequently, the work performed per minute amounted to 2,678 kg/m. Considering the real effect to equal 25 per cent, the result will be about 652 kg/m of work.

For greater precision in calculating the expenditure of energy in any kind of work, physiologists determine the so-called "respiratory quotient".

The respiratory quotient is the ratio of the exhaled carbon dioxide to the oxygen consumed in the same time. When stores of glycogen (animal starch) are decomposed in the body the respiratory quotient is 1. If fats are oxidised the volume of carbon dioxide is less than that of oxygen and the respiratory quotient equals about 0.7; during oxidation of proteins the respiratory quotient is somewhat greater, i.e., 0.8.

The caloric value of one litre of oxygen with different values of the respiratory quotient is known: during oxidation of carbohydrates one litre of oxygen corresponds to 4.5 large calories and during oxidation of fat—4.75 large calories.

From what source does the muscular apparatus derive energy for its work? In all animate and inanimate nature energy, the ability to perform work, is constantly being transformed from one form into another, for instance, electricity is converted to light and heat, and vice versa. Similar transformation of energy occurs in our bodies during work.

The work performed by our muscles, like the work of any living tissues, obeys the law of conservation of energy.

A muscle works by expending chemical energy which undergoes complex changes in the body and in the working muscle. The energy for muscular contraction is supplied by food which consists of complex chemical compounds.

The energy expended on moving a body carrying a load and walking at the rate of 4.4 kilometres per hour must be compensated by the production of a requisite number of calories from the main nutritive substances.

It is well known that all types of energy tend finally to be converted into heat. Physiologists utilise this to determine the important *relationship between nutrition and work*.

A man is put into an airtight and insulated chamber—a respiration calorimeter; the temperature of the air that comes into and goes out of it is very accurately measured, as is also the heat absorbed by its walls. The chamber is large enough for the man to sit and lie in. He is given food, each constituent of which has been tested as to the amount of heat (in calories) it would produce by combustion in a special apparatus. Accurate measurements of the total heat lost by the man (the body weight remaining constant) through breathing, radiation and evaporation, the heat of the food that has not been used up being taken into account, show that *the amount of heat lost by the human body is precisely equal to the amount of heat contained in the food which has been consumed.*

Similar experiments have proved that if the man in the respiration calorimeter performs some physical work, for instance, goes through the movements of riding a bicycle (the bicycle is stationary, only the pedals are moved and the number of revolutions recorded by a special meter which indicates the "distance travelled"), then the amount of work done, calculated by the general rules in terms of thermal units, will be found to correspond to a surplus heat loss equivalent to the energy expended by the subject on performing the assigned task. Every output of energy,

therefore, must be compensated by an increased energy intake.

This explains why one feels very hungry after any strenuous muscular effort.

It should not be concluded from the above that all the potential energy contained in the chemical substances (proteins, carbohydrates and fats) produces effective power. The efficiency of the human or animal organism ranges only from 17 to 37 per cent.

How long can muscles work? It is necessary to know this in order to be able to appreciate the "living engine" which each of us is using all the time.

The alternation of work and rest in muscles is called the rhythm of work. Not only the heart, but also all other muscles in the human body have their own peculiar rhythm, their own limitations as to the frequency with which they can contract.

For example, the muscles moving the forearm are capable of no more than 4 contractions per second, the masticatory muscles—6 contractions per second, and the muscles moving the fingers are capable of some 8 or 9 contractions per second, though well-trained pianists can achieve a somewhat higher rate.

Muscular activity cannot last too long, because fatigue sets in and *rest* becomes necessary.

Fatigue is a state of diminished capacity for work. How can this be proved? You sit at a table and put your forearm on the board of an *ergograph*, a device consisting of a pulley and a cord passed through it. One end of the cord is fastened to a finger (usually the middle finger), while a certain load is attached to the other end, all the other fingers being fixed by special clasps to provide a support (Fig. 7).

You begin lifting the load by the effort of the one finger; the cord is attached to a recording device which records every lift on a kymograph.

At first the lifting is easy, and the waves of curve increase, tracing what is known as the "staircase phenomenon", then a constant level is established (plateau), but not for long. Although you are conscious of making a maximum effort, the curve falls, exhibiting a skew (see

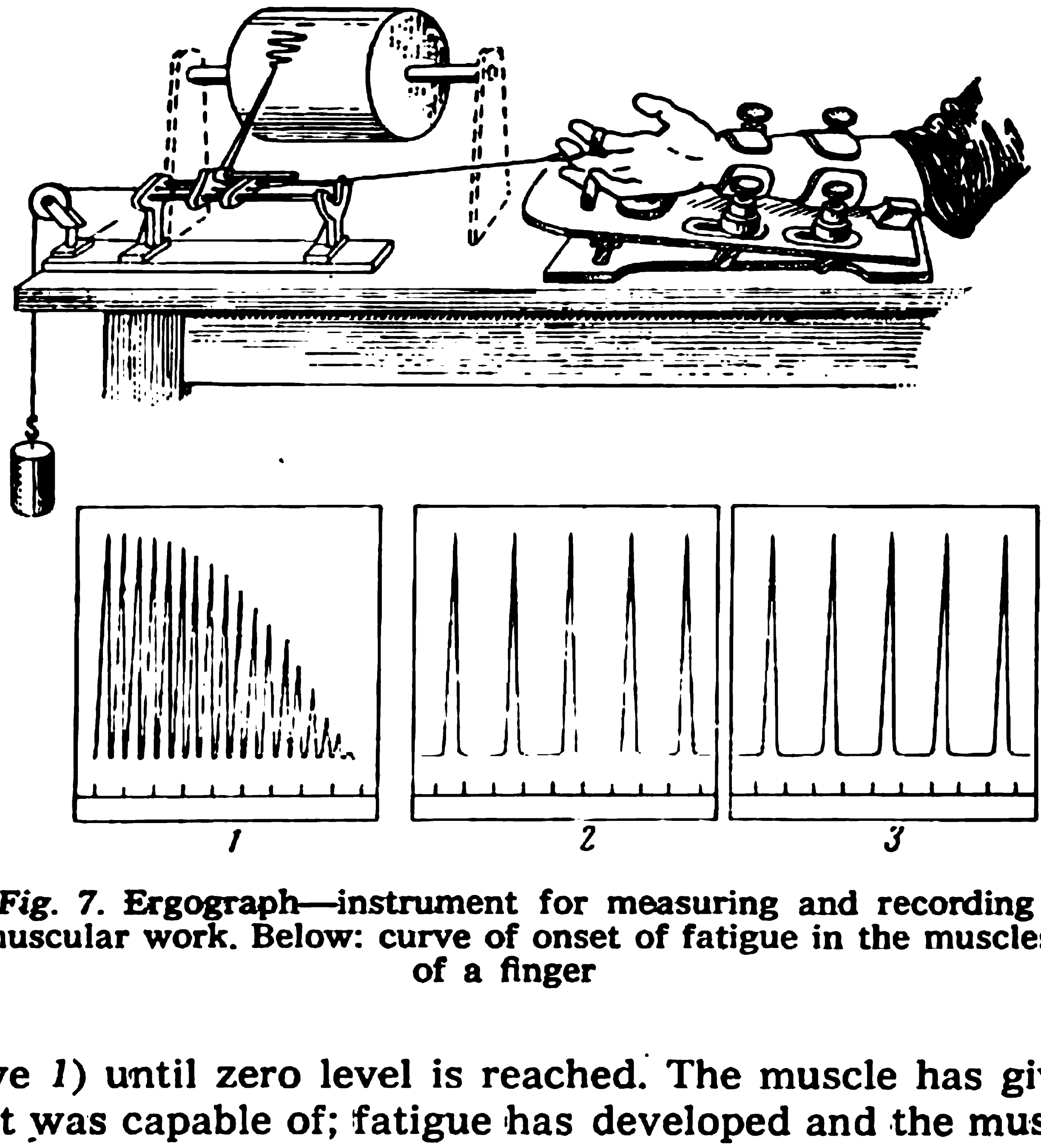

Fig. 7. **Ergograph—instrument for measuring and recording muscular work. Below: curve of onset of fatigue in the muscles of a finger**

curve *1*) until zero level is reached. The muscle has given all it was capable of; fatigue has developed and the muscle needs a rest. There are similar devices for studying the fatigue curve of the muscles moving the forearm, etc.

What is the cause of fatigue? There are many of them. However it has been established that fatigue is the result of the loss of efficiency not so much of the muscle tissue as of the nervous system, and primarily the cerebral

hemispheres where the higher centres of motor activity are located.

To prevent the loss of efficiency and, consequently, to raise the effect of work, the following requirements must be satisfied: (a) the optimum frequency of contractions must be observed, that is to say, the frequency (or rhythm) which is appropriate to the case in point (this being governed by the equipment used and by the number of muscles brought into play in the process under consideration)—(see curves 2 and 3); (b) the load must be neither too heavy nor too light, for it has been proved that a load below or above the optimum deprives the muscle of part of its potential efficiency.

Human Hand as the Body's Working Organ

We should like to dwell at some length on the characteristics of the hand as the most important organ of work, especially since it is of particular interest for the study and rationalisation of work processes. The mechanical aspect of the hand has been studied in some detail. As shown in Fig. 8, the skeletal structure of the arm and hand is such as to ensure them considerable freedom of movement.

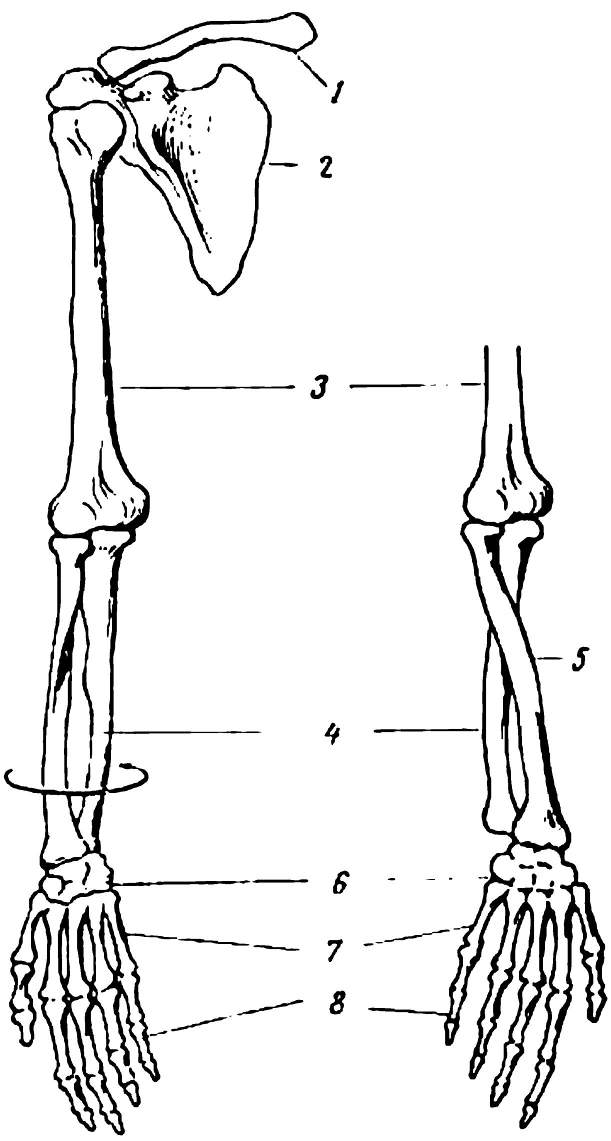

Fig. 8. Bones of arm and shoulder:

1—clavicle (collar-bone); 2—scapula (shoulder blade); 3—humerus (arm bone); 4—ulna; 5—radius; 6—carpus (wrist); 7—metacarpus; 8—phalanges (fingers). Forearm shown in pronation with possibility of supination

In studying the structure of the upper limb's muscular traction at the various joints we find that there are uniaxial, biaxial and triaxial joints (Fig. 9). They are surrounded by muscles which act on them and develop in the process of the development of man. The scapulohumeral joint, which is triaxial, has eight muscles. Four of them are attached to

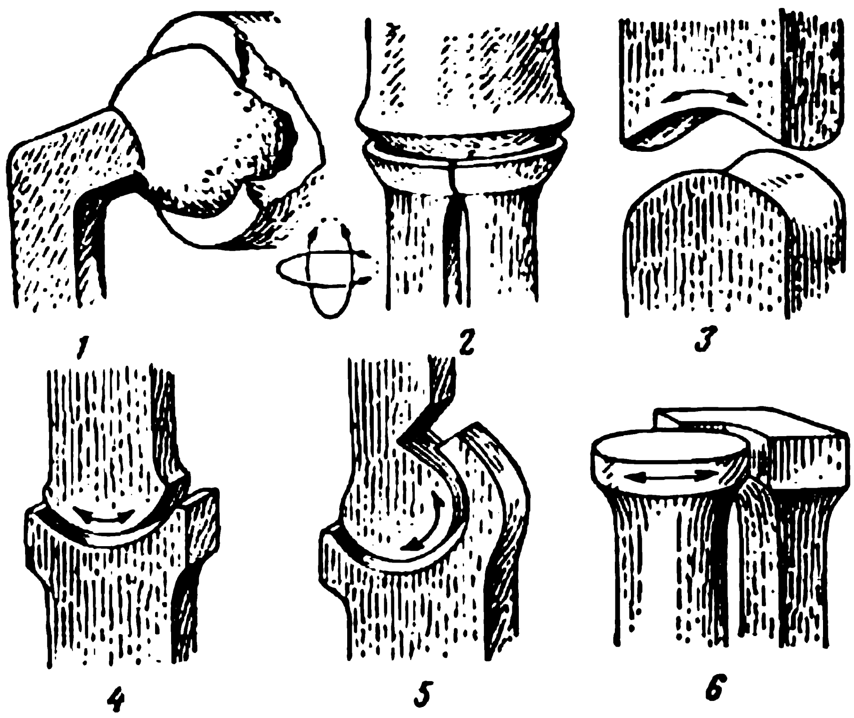

Fig. 9. Diagram of joint structure:
1—triaxial; *2*—biaxial; *3-6*—uniaxial

the head of the humerus, have very short lever arms and are therefore not strong; they are *weak action muscles,* although the speed of movement attained by the contraction of these muscles is very considerable. In the opinion of I. Sechenov, who made a special study of them, these muscles are not meant to move any load, but to bring the arm out of the state of rest and put it in the best initial position within the "working field". The "working field" or the working hemisphere is the circle described from the middle of the shoulder joint with the joint as the centre and with the radius equal to the length of the extended arm.

The activity of our arm within the working hemisphere is truly universal; there is not a single point in the inner

surface of this imaginary hemisphere which the extended arm cannot touch with its free end. Owing to the ability of the arm to flex in the elbow there is no radius within the hemisphere along which the end of the arm could not move by the shortest path. This can be particularly clearly observed by watching fencers.

The other four muscles of the shoulder joint are *strong action muscles*. The strongest of these muscles is the deltoid which covers the shoulder joint like an epaulet and, in addition to its main function of elevating the humerus, fixes the head of the humerus in the glenoid cavity of the scapula.

The elbow joint is *biaxial*. One might think that if our elbow had, like the shoulder, the ball-and-socket joint it would be more convenient, since in that case we would be able to describe with our forearm a circle like the one described by the movement from the shoulder joint, although of a shorter radius. But then the arm would bend at the elbow in all directions, i.e., it would lose the *stability* as regards the humerus which it owes to the uniaxial articulation between the ulna and the radius. It is therefore more rational to have a biaxial joint in the elbow. The stability of the limb in this joint can be compared to that of a door hanging on its hinges.

Another question that arises is whether it is reasonable for the forearm to be formed of two bones rather than one. Thanks to the pivot articulation between the head of the ulna and the radial notch, movement is possible around the *longitudinal* axis of the limb, producing what is known as pronation (turning the hand palm down) and supination (turning the hand palm up). In this way we obtain the desired third axis of rotation and ensure the stability at the elbow, which is so essential in work operations, for instance, in working with a screwdriver.

It would seem that two muscles—a flexor and an extensor—might suffice for the uniaxial humeroulnar joint. Actually, however, three more muscles are added to these

two, one of them being the familiar biceps brachii. The biceps performs two functions: being attached at one end to the radius, it serves to pronate the forearm and only after the completion of this pronation does it begin to flex the arm in the elbow joint. It is for this reason that an athlete who wants to show off his "biceps" always starts by clenching his fist with the palm of the hand facing the body. Fig. 10 shows the contraction of the biceps and its synergist, the branchialis muscle, in lifting a weight.

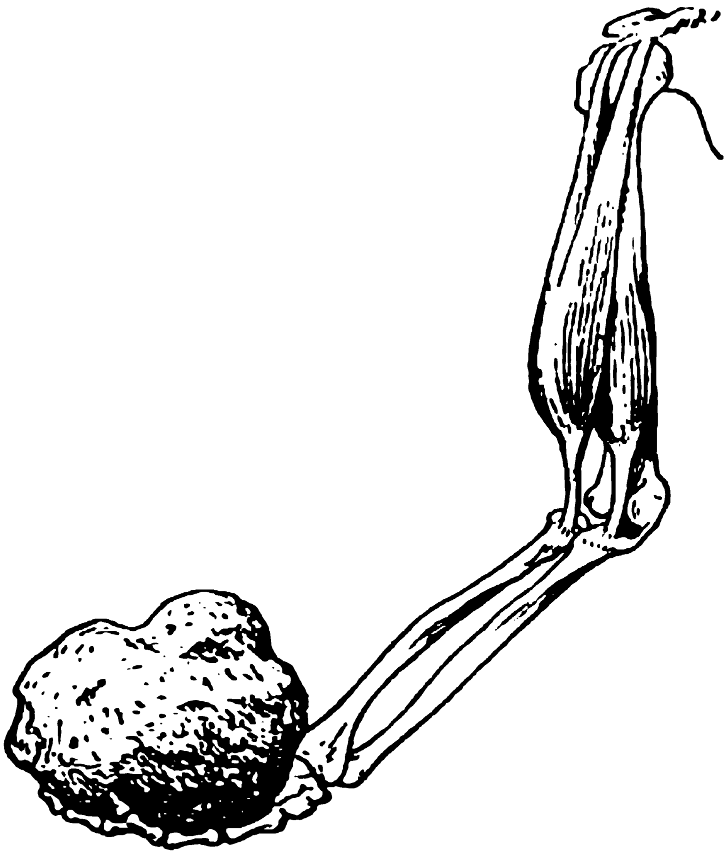

Fig. 10. Biceps and its synergist in action

The radius has five rotatory muscles instead of the two we might expect for a uniaxial joint. They are active, for instance, in the movements of screwing, which are so important in technological processes. As for the biaxial radiocarpal articulation, it has six muscles: two pairs of muscles are located on either side of the palm and the third, between them.

The biaxial radiocarpal and the uniaxial elbow joints produce in combination a triaxial articulation (ball-and-socket), of the type which we thought would be best in the elbow—by analogy with the shoulder joint. Yet the wonderful mechanism of the human arm and hand, elaborated by nature in the process of evolution, does not end with this.

To the movements in the shoulder and elbow which we have described are added the movements of the fingers and thumb. Moreover, we can act not only with each

finger but with the individual parts of the fingers—the phalanges.

Movements involving the apposition of the thumb, which has its own very strong muscles, play a big part in work. Apposition enables man to grip different objects. No animals except monkeys and apes are capable of this movement.

Since all the parts of the arm and hand can work together, in pairs, or separately, man can perform the immense variety of movements which are peculiar to work processes.

Since all these mechanisms can work in various combinations, man can use different joints for movements requiring differing degrees of exactitude. For instance, when an object is worked with a hammer or a chisel, the shoulder joint merely roughly stabilises the limb, as its structure allows of relatively large movement of the arm in space. The elbow joint permits of more precise stabilisation. The finest movements, for example, when working with a micrometer screw, are made with the carpal joint and the phalanges. The same holds true for writing and for playing musical instruments.

In all cases the hand is the final and decisive element of movement. Its function can be briefly summed up as follows: The afore-described articulation of arm and the hand enables man, by moving his arm, to translate his hand rectilinearly, i.e., along the shortest path, along all the radii of the "working hemisphere", the hand preserving its freedom to make both big and small movements in all positions.

Finally it is necessary to say a few words about the articulation of the arm with the motor mechanisms of other parts of the body, viz., the shoulder girdle and its own muscular tractions.

The upper end of the humerus is attached to the scapula where the latter joins with the clavicle. The shoulder girdle is not closed; it is so constructed that the clavicle

with its medial end articulates directly with the sternum (breast bone) while the scapula is attached to the ribs indirectly—by means of strong muscles.

In this way the following is achieved:

1. Since the scapula (shoulder blade) and the clavicle (collar bone) can move freely in several directions, the head of the humerus acquires one more "degree of freedom" of movement. For instance, in shrugging our shoulders we bring into play only the muscles of the upper shoulder girdle. The mobility of the point of attachment of the arm enables its free end to make sweeping movements, which is very important for some types of work, for instance, throwing the javelin. In this instance the muscles of the shoulder girdle act in accord with those of the "stem part" of the arm, giving them additional strength.

2. The shoulder girdle muscles often perform an auxiliary, although very essential, type of work: they firmly *fix* the articular surface of the scapula, lending firmness to the whole of the arm. This system of attachment is necessary, for example, when the arm delivers strong and accurate blows without taking any preliminary swing. In this particular case the body profits from the absence of direct attachment between the scapula and the thorax, since the reverberations experienced by the upper limbs are not transmitted to the spine to which the shoulder blade is attached, and do not reach the spinal cord. The collar bone and the ribs act in this case as *springs*. Thus the spinal cord and the cerebrum are spared shock even in heavy blows dealt by the arms.

Artificial (Mechanical) Hand

Engineers and machine designers have for ages dreamt of machinery which may do all the work of man and beast.

The structural peculiarities of some animals, birds, reptiles and even insects have served as models for the construction of various mechanisms whose appearance and working principles resemble the structure and functions of the organs of these animals. For instance, the Roman battering ram for attacking fortress walls was built in the form of a ram's head (known as having a particularly strong frontal bone); a body of Roman troops in close formation protected with their shields joined over their heads was called a tortoise; the first grindstones were constructed so as to resemble the human hand; the wings of aeroplanes bear some resemblance to those of birds; the caterpillar tractor reproduces the movements of an insect's larva; the fins that skindivers put on their feet copy the construction of the limbs of pinnipeds.

This use of the natural appliances of animals to assist human designers is known as *modelling.* Modelling is also used to facilitate processes of cerebration, i.e., to assist man in the most complicated form of his activity. This does not mean, however, that in his inventions man is always guided by what he sees in animate nature. It would be still more erroneous to assume that nature itself is constructed along certain rational principles, like the principles of engineering which reveal the social genius of man. Such an assumption would be purely mechanistic or, on the other hand, might lead some people to the idea that the chief engineer, the builder of nature as a whole, is God, which would identify science with religion.

The analogies between a machine (lever) and the human arm, as well as the limbs of animals may prove useful, because the chief laws of motion of matter are valid in both animate and inanimate nature. In other instances direct modelling, without considering the definite differences between what is living and what is not, leads, instead of progress, to stagnation in technology. This happened, for example, in the case of inventing heavier-than-air flying apparatus. The idea of bird-like flapping wings

prevailed for five centuries, but was finally proved untenable and was abandoned for that of the propeller; the principle of rotation of an electric conductor in the magnetic field has no parallels in nature but it was this principle that opened up broad prospects for modern technology, etc. Sound location in bats was discovered after the invention of radar.

But sometimes it is absolutely essential that a design engineer should know the anatomy of joints and muscles. This knowledge is necessary for constructing the various mechanical manipulators used in hot shops, atomic laboratories, for work in the depth of the oceans, etc. Then there are micromanipulators constructed on the same principles as the fingers and used where the movements of the human fingers are not sensitive enough for the work in hand.

In some cases very good use is made of the connection between the mechanical appliance, the working apparatus, and the activity of the human hand (not only its muscular but also its nervous apparatus). A good example of this is the artificial hand with electronic regulation (Fig. 11).

An artificial hand (or arm) regulated by nervous impulses and capable of reproducing the corresponding movements of the fingers, wrist and the whole arm, is necessary above all to those who have lost one or both upper limbs. This idea first arose at prosthetic appliance institutes and thence spread to factories in the form of very promising automatic devices.

The special feature of the controlled artificial hand is that its operating mechanism imitating the closing of the hand (the apposition of the thumb and fingers) is based on utilisation of very weak electric currents generated by the excitation of the flexor muscles of the hand. These biological currents are amplified by radio-engineering devices and are transmitted to special throttles regulating the action of the oil pumps. These are connected with a system of levers which contract or relax the hand built

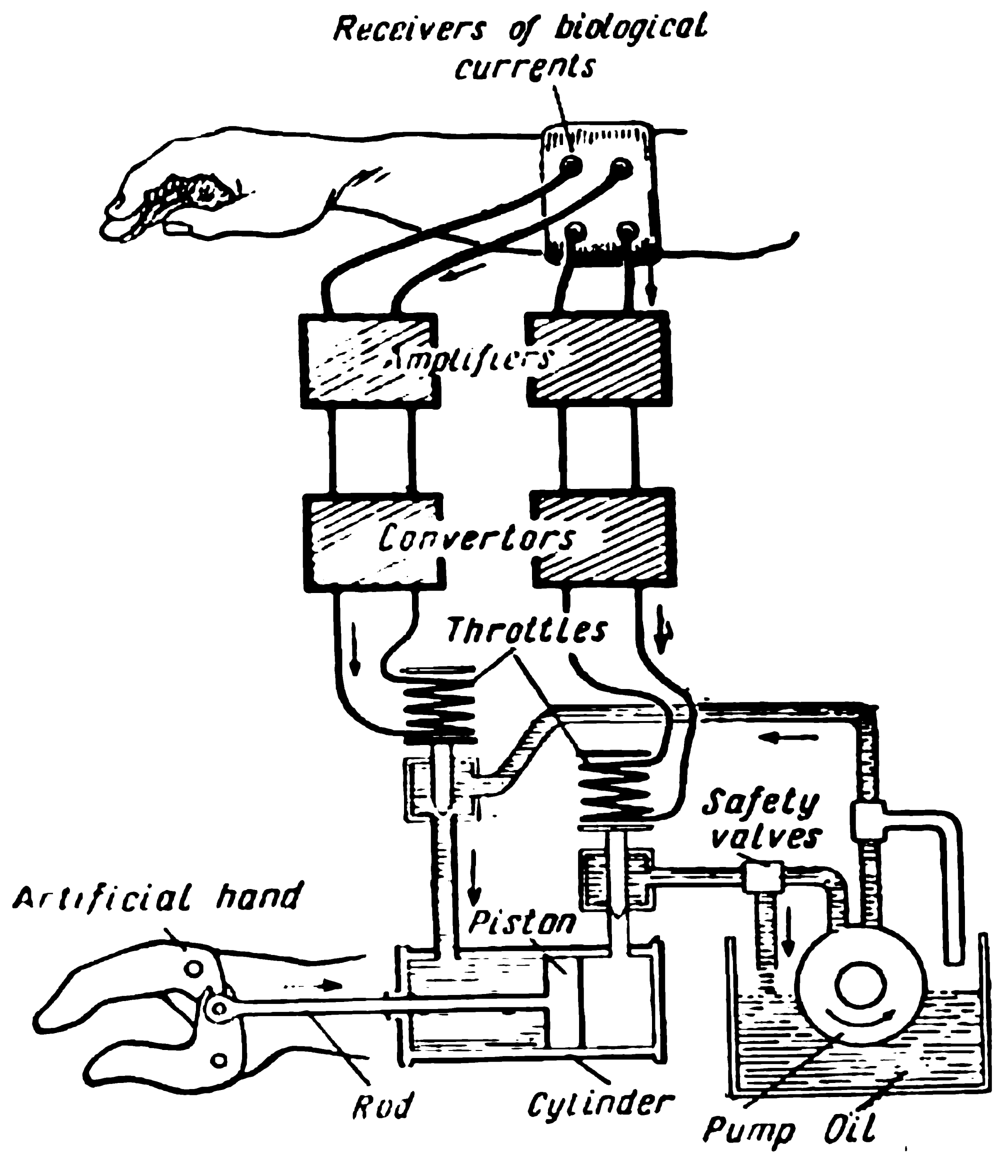

Fig. 11. Mechanical hand controlled by biological muscle currents through electric amplifiers

on special joints or hinges. The receivers of the biological currents of the muscles regulating the action of this mechanical model hand are located directly on the skin of the forearm over the corresponding flexors of the hand, like the electrodes of an electrocardiograph, which are placed on the skin in the region of the heart to record the biological currents that characterise the work of the heart. The biological currents make the artificial hand work.

It suffices slightly to contract the flexor muscles or even merely to think of bending the fingers for the fingers of the mechanical hand to contract. The more vigorous the contemplated movement, i.e., the stronger the biological

currents sent to the apparatus, the more intensive the work of the pumps and the stronger the grip of the automatic hand.

With the progress of electronics and of our knowledge about the work of the brain, it will be possible to satisfy the needs not only of those who have lost the use of their hands and to help them to work, but also to transmit the biological currents directly from the motor regions of the brain instead of from the motor apparatus (muscles), thereby effecting the intended movements in a series of actions which will be stronger and more accurate than anything hitherto achieved. This will supply new methods and new data for studying physiology as applied to problems of work.

At present designers in the U.S.S.R. (A. Kobrinsky, V. Gurfinkel and others) are working on an artificial hand employing feedback with a system of conductors correcting the force and effect of the movements performed by the automaton. In this way it will be possible directly to model the muscular sense which is the decisive factor in man's operating any sort of machine, and about this we shall have more to say later on.

* * *

It is clear from what has been said above that the physiology of physical work is intimately connected with the progress of anatomy, with the physiology of exercise and the study of man's natural movements.

Up to the nineteenth century most of the operations of lifting heavy loads and working different materials were done manually, the muscular energy of man and beasts of burden being almost the only basis of industry and agriculture. The nineteenth century was characterised by the introduction of steam power into industry and a rapid development of science and technology.

This progress yielded abundant fruit in research into the laws governing the movements of living beings and in

the further development of physiology, labour organisation and working conditions. The general laws regulating the movements of men at work were brought to light (by Sechenov) and the importance of the transformation and conservation of energy in physical work for the understanding of metabolism in nature as a whole was made clear.

These discoveries made in the middle of the nineteenth century gave rise to modern energetics and enabled scientists to gain an insight into the essence of the transformations taking place in both animate and inanimate nature. The problem of nutrition was posed as the problem of making good the loss of energy incurred during the performance of physical work. The methods that were elaborated at that time (for measuring gas exchange, etc.) are used in science to this day.

A similarity was discovered to exist between the individual parts of the skeleton and those of machines. The first inventors and designers of mechanisms often modelled the levers, cranks, connecting rods and the like after their own arms and legs. This enriched technology and at the same time strengthened its ties with physiology as applied to work processes.

But that was not all. Along with the continued improvement of machinery and the introduction of electric and other types of motors, it became possible to reproduce the processes regulating muscular contraction with the aid of electronic appliances, to construct the artificial hand and other devices which open up new prospects before physiology and the organisation of labour not only of disabled persons but also of able-bodied workers and engineers.

CHAPTER THREE

CONDITIONED REFLEXES AND FORMATION OF BEHAVIOUR

Methods of Studying the Structure and Function of the Brain

Modern physiology and labour hygiene aim at studying the activity of the organism as a whole; they study the work not only of the muscles, but also of the brain as the main regulator of behaviour, and strive to determine its role in the acquisition of skill and formation of correct working habits. As time goes on, man, the creator of all of our material and spiritual values, himself increasingly becomes the object of study. This study is carried on by the methods of the exact natural sciences. The most important—and at the same time the most difficult—requirement in analysing the highest manifestations of behaviour which include mental work, is for the researcher to preserve a detached and impartial attitude that is characteristic, for example, of the study of the energetics of work, to be able to establish how the consciousness of an individual is born in the process of work, and to observe the dynamics of the creative process.

The investigations of I. M. Sechenov and I. P. Pavlov, the great physiologists who laid the foundation for a scientific and objective study of higher nervous activity,

prove that the science of the brain can, and must, rise to the level of the other branches of natural science, which are based on the acceptance of the evolution of all living matter. The physiological methods of brain study employed today at many laboratories and institutes for investigating the work process enable the researcher not only to gain detailed knowledge of the structure and function of the brain, but also to reveal the laws specifically governing human mental activity, which may be used for organising a system of wholesome and enjoyable work in keeping with the requirements of physical and mental health.

It is true that the structure and physiological importance of the higher parts of the brain have not as yet been fully studied. The results of the research already accomplished are, nevertheless, of considerable importance for clinical practice (for example, in controlling occupational diseases) and appear very promising as regards scientific rationalisation of work. Knowledge of the laws governing man's mental activity, as well as detailed knowledge of the functions of all the parts and centres of the brain, will enable us to develop scientific methods of preventing and treating mental and nervous disorders resulting from incorrect working habits and general regimen, and at the same time will give us valuable data for correct organisation of the creative work of millions of people who are taking up new forms of production. Knowledge of the laws governing the development of the brain will help further to improve the methods of educating the rising generations, to provide for their all-round mental and physical development and to solve many problems of their polytechnical training.

What are the conditions under which physiologists are studying problems of the brain and work?

In the U.S.S.R. there are special institutes for the study of the central nervous system, especially its highest part, the brain, which is the material basis of consciousness.

The methods employed by investigators of the structure and function of the brain are fairly complicated. The study of the brain structure involves techniques of modern microscopy, while the activity of the brain is studied by special conditioned reflexes, as well as chemical, surgical, electrophysiological and other methods.

The work of Renaissance anatomists constituted the first investigations of the brain. These dissected the human brain and found it to consist of grey matter (nerve cell bodies, their dendrites and unmyelinated portions of axons) and white matter (myelinated nerve fibres, the conducting units). They described the numerous convolutions and fissures on the surface of the brain and deep within it.

The anatomists wondered about the complex structure of the brain, but had no idea of its functions and contented themselves with giving descriptive names to its parts. Some parts of the brain surface they named areas, others—fissures. Certain parts were given names that sound odd to us (for example, "hippocampus", "pyramid", "sella turcica", etc.), although they have persisted to this day. The physiology of the nervous system is indebted to these fundamental works which helped in elucidating the general structure of the nervous system (Fig. 12).

The brain is a semiliquid gelatinous mass containing proteins, lipoids and some other substances, and abundantly supplied with blood vessels.

A modern laboratory where the structure of the human brain is studied may be likened to a factory consisting of several shops. In the first shop plaster moulds are made of the dead people's brains that are of some interest, while the brain substance proper is made to solidify after the mould has been prepared. Following this it is conveyed to the shop of large microtomes, i.e., instruments resembling planing machines, or rather big razors weighing several kilogrammes each and cutting very thin sections (no more than a few microns thick) of brain tissue,

thereby dividing the brain into 30,000-35,000 microscopic layers which are stained with various aniline dyes, after which each section is placed on a separate slide. The large collection of slides thus obtained enables the researcher to study any layer of the brain separately and to trace the connections between them.

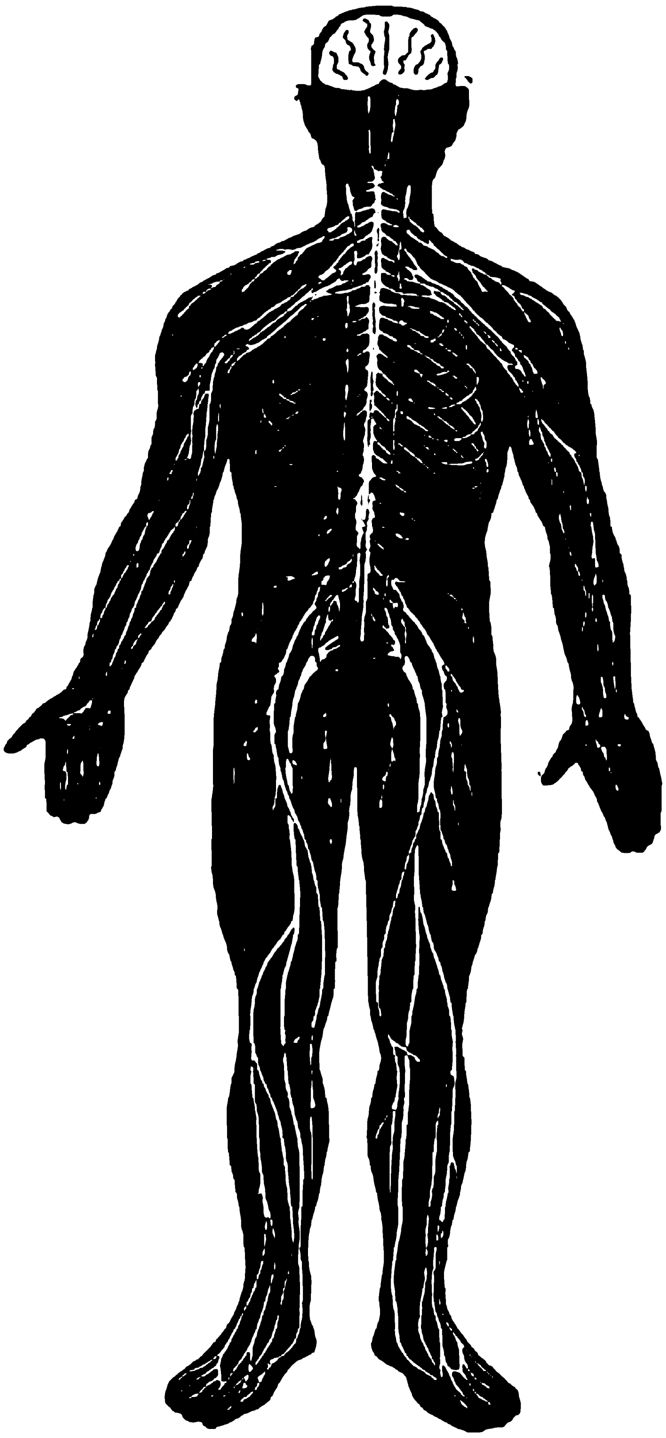

Fig. 12. Diagram of nervous system

A nerve cell with its numerous processes (dendrites and axons) is called a neuron. The connections between the processes and the regions of communication between them (synapses) are very important for physiology. The science studying the structure of the nerve cells and their processes, as a kind of living architecture, is called cytoarchitectonics (from Greek *kytos*—container, cell).

The various methods used by modern science have helped scientists to establish that the brain has not only numerous fissures and convolutions but also about 200 areas with variously distributed cells of different microscopic structure. We do not as yet know all the functions of the different combinations of cells, nor those of all the minor fissures and gyri. The physiological function of each individual part of the brain has

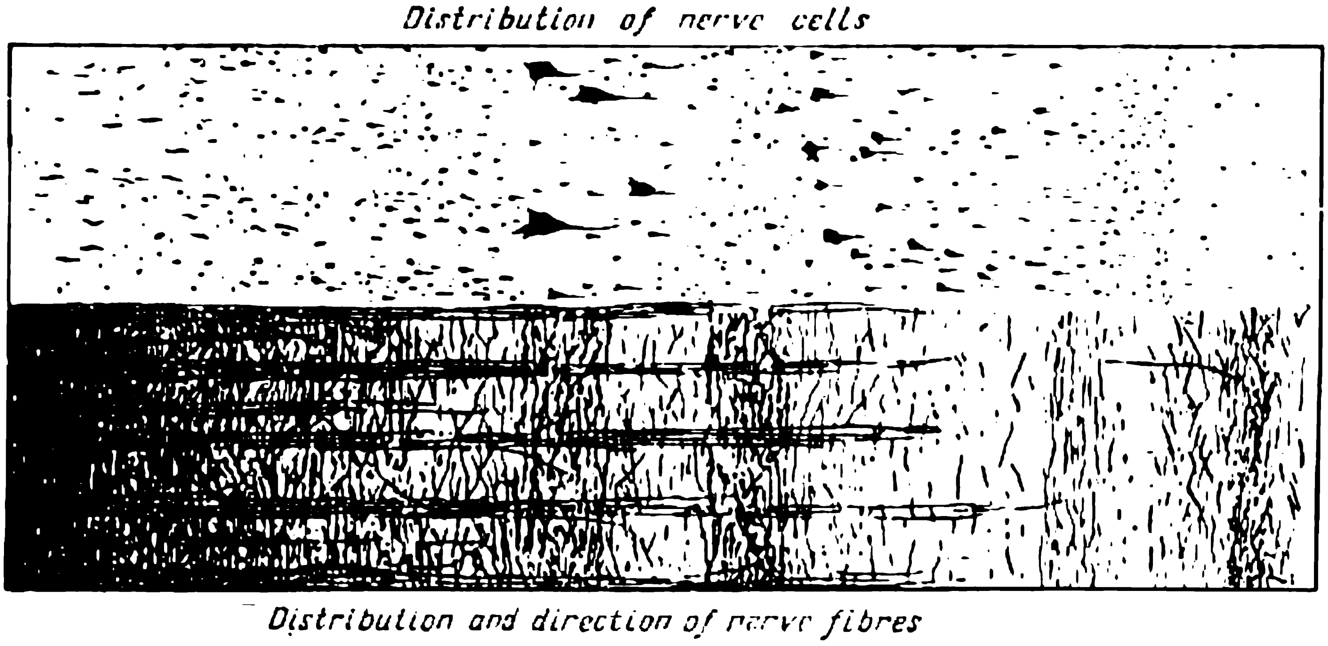

Fig. 13a. Microscopic view of the fine structure of the cerebral cortex

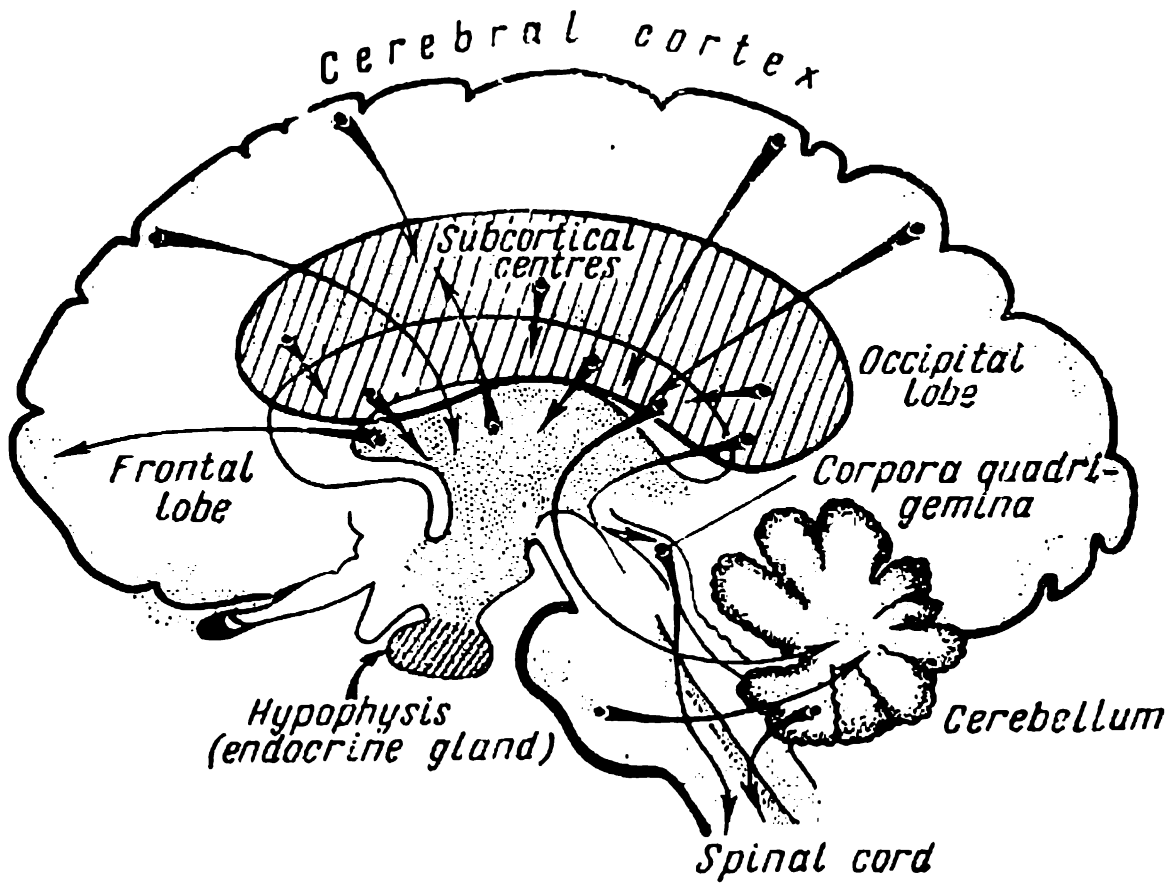

Fig. 13b. Structure of the human brain. Arrows mark most important nervous connections between different parts of the brain, the cerebral cortex and subcortical centres in particular

not yet been fully established, although science is gradually clarifying the complicated picture of the structure and localisation of the cerebral centres. Now we can distinguish the visual centre from the auditory and other centres, a thing which was impossible until the Russian histologist V. Betz originated the science of cytoarchitectonics in 1874. Especially important for the history of physiology was the investigation of the part of the brain which is associated with the movement of the muscles (motor centres), the centre controlling the movements of the hands in particular. These centres are located in the anterior central gyrus of each hemisphere and consist of several layers of nerve cells (Fig. 13*a*). When these important centres and the paths leading to them that lie in the subcortical ganglia (Fig. 13*b*) are injured, for instance, by poisoning or haemorrhage, the hand is paralysed or its movements are impaired.

However, the study of the brain is not limited to histological and morphological investigations. There are methods of observing the changes in the chemical composition of the brain substance and the metabolism taking place in its cells during nervous activity. The study of the inorganic matter contained in the brain has been carried on for a long time through combustion of the brain substance in special electric furnaces. Very thin sections of the brain were burned and their composition was studied by means of a spectroscope. The studies showed the brain to contain traces of many metals.

The brain has a very complex chemical composition: it contains potassium, magnesium, calcium, phosphorus, iron, gold, copper and other elements—all in minute quantities.

The physiological functions of the brain, like those of all other tissues, are based on metabolism, and this distinguishes the activity of the brain from all cybernetic devices.

Today metabolism in the brain is studied by means of radioactive *isotopes*, which is the finest and most sensitive method. In this method, Geiger counters detect radio-

active particles introduced into the organism with food, air, etc. Like a number of other methods, this one is employed for the study of the living brain. The science of the brain owes many of its very important discoveries to experiments on animals at different evolutionary stages, which shed light on the activity of the brain of man, whose nervous system is the highest form of organic matter with the most complex metabolic processes. It has been shown experimentally by E. M. Kreps that the higher the stage of the animal's evolution, the more intense the metabolic processes taking place in its brain.

Experiments with the introduction of tracer sulphur (S^{35}) into the blood of animals in A. V. Palladin's laboratory have shown that of all the parts of the nervous system the cerebral cortex has the highest rate of metabolism. The chemical composition of the excited parts of the brain differs slightly from that of the parts which are in a state of rest. The so-called motor area controlling the work of the muscles of the limbs shows a more intensive phosphorus metabolism than the visual or auditory centres (V. A. Engelgardt, *et al.*).

A factor of importance in the physiology of man at work is the amount of blood carried to the brain. This amount decreases appreciably during sleep.

It was established long ago by Mosso's method of studying the flow of blood to the brain that, if a human being is laid on a sensitive balance with his head and feet in equilibrium and is made to do some hard thinking, the pointer moves towards the head, that is, a positive shift in the flow of blood to the brain is observed. When the person on the balance discontinues his mental efforts, the balance returns to equilibrium. Today such weighing is done by means of special electromagnetic devices with cathode amplifiers (ballistography), which makes it possible to establish not only the fact that the subject is performing mental work, but also the fluctuations in the

Fig. 14. Studying the biological currents of the human brain in clinical experiment. Receiving electrodes contact the skin of the head. The currents are recorded by means of electronic amplifiers and oscillograph

intensity of this work. During the experiment the movements of the subject are not restricted in any way.

Another precise method of investigation, the electrophysiological method, shows various fluctuations of the electric potentials in groups of nervous centres, occurring during mental work and detected with the help of cathode valve-amplifiers used in radio and television engineering. By applying electrodes to different parts of the exposed brain (in man—to different parts of the scalp—) "action currents" generated in the brain under different conditions of work are studied in physiological laboratories (electroencephalography, Fig. 14). In this way it is possible to study the excitation and inhibition processes taking place in different parts of the brain while it is working or is in a state of rest.

Electroencephalography enables the investigator to see the difference between the functioning of the brain of healthy and sick people and between the waking and sleeping states, i.e., to watch the processes operating in the brain, in dozens of spots of its surface simultaneously, and even to conduct these observations from a distance: with the assistance of special radio transmitters one can study the action currents in the brain of a pilot flying at high altitudes.

It should be mentioned here that the encephalograph provides a means of studying the *physical* changes in the brain at work but not of reading the *thoughts* of the person, as some are inclined to believe. It is absolutely impossible to read anybody's mind, however near or far one may be. One must never attempt to identify the physical phenomena and physiological processes occurring in the brain with the processes of thinking, for that would be a crude mechanistic approach.

"One day we shall certainly 'reduce' thought experimentally to molecular and chemical motions in the brain," Engels wrote, "but does that exhaust the essence of thought?"*

* F. Engels, *Dialectics of Nature*, Moscow 1954, p. 328.

The physical and chemical methods of investigation tell us much about the behaviour of man at work. Yet the central place in the study of the functions of the brain belongs to Ivan Pavlov's conditioned reflex method. Other neurological methods, such as the study of the speed of nervous reactions, the sensitivity threshold of the sense organs and the electrical potentials of the skin, as well as the numerous psychological observations, are fairly important as auxiliary methods, but they can be variously interpreted and do not reveal the most essential feature of the activity of the central nervous system, its coupling function, i.e., the formation of temporary connections.

Ivan Pavlov's materialist teaching, firmly substantiated scientifically, has freed experimental psychology from mysticism and the idealist nonsense of the past, and has made it possible to solve correctly the problem of man's development in work. That is why Soviet physiologists and psychologists take Pavlov's teaching as a point of departure and why his methods are widely used in laboratories both in the Soviet Union and abroad. Life has clearly shown this materialist teaching to be irrefutable. The Pavlov teaching of conditioned reflexes also applies to the organisation of mental work: it is also a weapon for combating the religious view of work as a "curse inflicted by God" for the sins of humanity. Science has proved the contrary to be correct, namely, that work is an essential need of the human organism, that in the process of evolution work created the human mind and hand, and that work is necessary for the development of every individual human being. It follows from Pavlov's teaching that in the course of his life a human being cannot exhaust all the potentialities of his brain's coupling function with respect to forming new nervous connections. The achievements of modern science and the socialist reorganisation of the social relations have put an end to the myth of the existence of some select "blue-blooded" people, to the belief that the brain of some people, for

instance, Europeans, is so constructed that they are preordained to rule colonial peoples, allegedly incapable of being civilised and of managing their own state affairs.

The racist theory of fascism that doomed millions of people to extinction in concentration camps has been condemned by history. The assertions of racists that the brain of the "coloured", as they contemptuously call the peoples of Asia, Africa and other continents, is on a lower level of development than that of the Europeans, find no confirmation in science. The aforesaid peoples were deprived of educational and cultural opportunities under colonial oppression, hence the allegations of the inferiority of certain races. The materialist teaching on the brain thus offers a firm basis for the advanced ideas and lofty humanism which are characteristic of Soviet science.

The teaching that the same laws govern the cerebral functions of all people shows the democratic aspirations of I. Sechenov and I. Pavlov who were brought up in the spirit of the nineteenth-century Russian philosophy of enlightenment as professed by A. I. Herzen, V. G. Belinsky and N. G. Chernyshevsky. The ideas of Pavlov and Sechenov will never become outdated, because to this day they help in the struggle for peace waged by the world's best minds.

Essence of Pavlov's Teaching on Higher Nervous Activity (Behaviour) of Animals and Man

The Soviet science of human behaviour is developing on the basis of dialectical materialism, a teaching which considers matter in motion primary, and consciousness, or the mind, secondary, the latter having appeared in the process of the development of matter. This idea underlies the whole of Pavlov's physiological conception, which is itself a natural scientific basis for dialectical materialism.

Man did not arrive immediately at a proper understanding of the problems to be solved by the science of behav-

iour described in the works of I. M. Sechenov and I. P. Pavlov. The knowledge of the brain was developing parallel with the achievements of both biology and technology. The growing complexity of the instruments at the disposal of man who is remodelling nature impels us to perfect Pavlov's methods of study and seek new paths in our study of the physiology of work.

Science and technology do not everywhere serve the cause of progress and peace among the nations. In the U.S.S.R. each new achievement of biology—the science of life—is utilised for the well-being of the people, while in the capitalist countries, as often as not, the attainments of science are used by the capitalists against the working people and to subjugate and enslave other countries.

Idealist scientists often distort the essence of new discoveries in physiology and neurology and with the support of the big bourgeoisie try to reconcile them with religious dogmas. For example, the physiologist C. Sherrington, who had made a considerable contribution to the study of the central nervous system, at the end of his life advocated agnosticism* and opposed Pavlov's teaching by defending the dogmas of mediaeval scholasticism and asserting the immortality of the soul. For this he was severely criticised by the great Russian physiologist.

The study of the human mind in development, as revealed in work, enables us to form a correct materialist idea of the origin of man's consciousness and thereby once more to demonstrate, this time in the light of physiological science, the fallacies and errors of the idealist world outlook, especially as regards work.

Dialectical materialism teaches that all of nature is knowable, that all obstacles and difficulties in the way of cognising the surrounding world can be overcome by using the criterion of social practice and by studying

* Agnosticism—a doctrine denying the possibility of knowing scientifically the laws governing the world around us.—*Ed.*

matter in motion as it really is and stripped of idealistic fancies.

The teaching of behaviour elaborated by the physiology of the brain is based on creative Darwinism which has shown that all manifestations of animate nature, including heredity, change under the influence of the *conditions of existence* viewed from a historically concrete standpoint.

The organism and its environment are inseparable. A living organism's reactions to the external environment are as varied as the changes occurring in the latter.

Pavlov has shown that all the reactions of an animal's nervous system, constituting the animal's behaviour, can be divided into inborn reactions (the food and defence reactions) and those acquired in the course of its individual life. Both are constantly changing and improving in conformity with the environment. The acquired reactions, however, change much more readily, since they are more flexible and mobile than the inherited ones.

It is more difficult to observe the changes occurring in instincts, which take a long time, than it is to discern the elaboration of conditioned reflexes which literally form before one's very eyes.

It must not in any way be assumed that in the course of its life an organism acquires the reactions it wants for its own convenience. All anatomic and physiological improvements are regulated in animals by laws of adaptive changes and not by their wishes. If its reactions or reflexes did not conform to the requirements of the environment, the organism would perish or, at any rate, fail to produce viable offspring. It should be noted that the sex instinct and care for the offspring are also connected with a multitude of inborn reactions, which, however, do not show all at once but appear in the course of an individual's development, with the maturation of its endocrine glands (mainly the sex glands).

The main inborn reflexes or reflex chains, in which the end of one action gives rise to the beginning of another, are called instincts. Important as they are, they are not enough for purposes of adaptation. Whenever a new condition arises in the environment, for instance, when the climate changes, new kinds of food become available or new enemies appear, corresponding changes take place in the organism's entire behaviour, i.e., in its reflexes, and new adaptive behaviour patterns, commonly called habits, develop in its central nervous system.

The more viable an animal, the more numerous its acquired reactions, while its inborn reactions change much more slowly. Getting food, resisting the enemies, giving birth to offspring and protecting their lives are reactions with the most durable and permanent connections in the higher part of the nervous system. Along with these there appears a new class, or type, of reactions of the nervous system—reactions connected with the highest forms of adaptation. They are conditioned reflexes which, without knowing the mechanism of their formation, Sechenov called "reflexes of the brain".

The most important property of conditioned reflexes is that they correspond to temporary nervous connections in the brain.* The nervous path, or arc, of an acquired reflex running through the cerebral cortex of the higher animals is less stable than the instinct connections in the lower parts of the brain. A conditioned temporary connection is formed by coupling or contact, with an analogy to be found in communications engineering, for instance, the function of automatic telephone exchanges, and can be reproduced in electronic models. The connection oc-

* Some authors distinguish between conditioned reflexes and temporary nervous connections. The first conception is more limited, for a temporary connection may be established outside a complete reflex arc. In treating the problems of work this distinction is not essential.

curring in nature is, of course, infinitely finer and more perfect than any contact devices used in technology.

How is reflex activity formed? How does a nervous process operate in the brain when the act is an elementary one, for example, feeding and all that goes with it? It

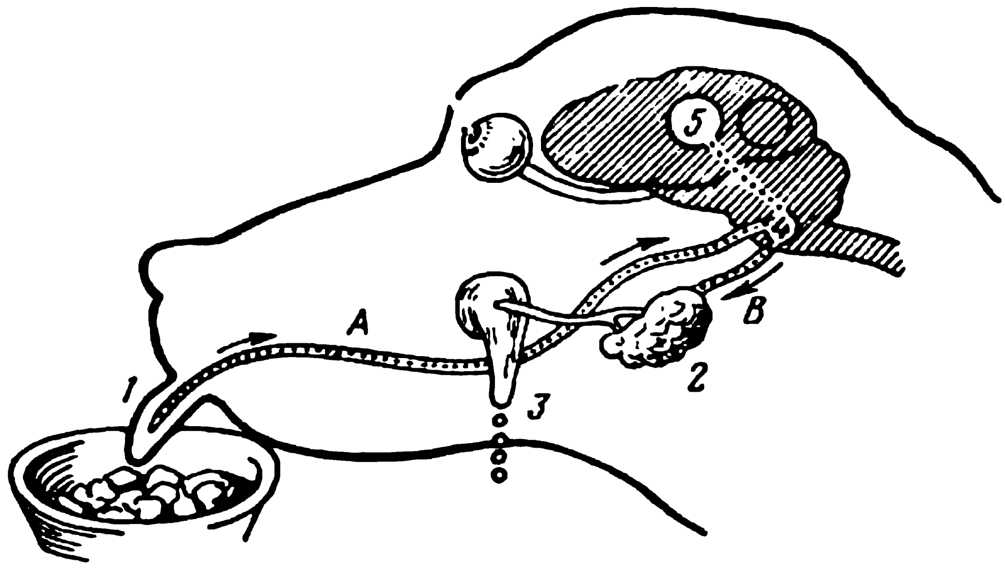

Fig. 15. Diagram of conditioned reflex arc:

1—tongue; 2—salivary gland; 3—fistula of salivary gland; 4—salivation centre in medulla oblongata; 5—representation of the alimentary centre in the cerebral cortex; A—afferent; B—efferent nerve of salivary gland

was while observing what was happening to food in the animal's oral cavity in the laboratory that Pavlov laid the foundation of his teaching on higher nervous activity and demonstrated the materialist, knowable nature of this activity.

Suppose we are feeding an animal which has a fistula in the duct of its salivary gland. The nervous excitation—a series of afferent nervous impulses—moves from the tongue along the corresponding nerve to the salivary centre in the brain stem (Fig. 15). This is the first, afferent, part of the inborn reflex arc, the path of the basic unconditioned salivary reflex with which a mammal is born. After being processed in the medulla oblongata (in its salivary centre), a matter of tenths of a second, the excitation is transmitted to the efferent nerves and reaches the salivary gland. The gland secretes saliva of

a certain chemical composition, and this is the end of the reflex. The transmission of the nervous current along this arc results in a definite, biologically purposeful activity of the organism: the discharge into the oral cavity of saliva which moistens the mouth, thus facilitating the

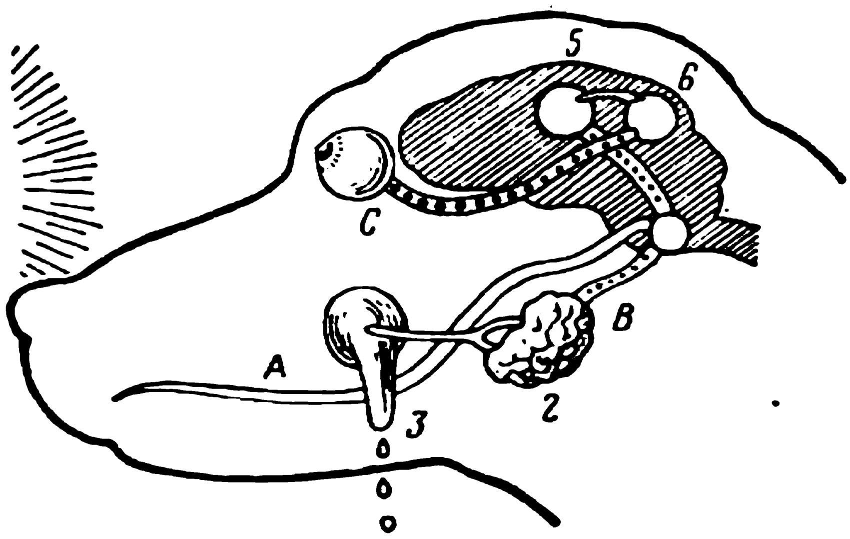

Fig. 16. Elaboration of conditioned salivary reflex arc through reinforcement. Figures indicate the same parts of the brain as in Fig. 15. 6—visual centre in cerebral cortex coupled with centre of unconditioned reflex by means of temporary bond. *B*—optic nerve

swallowing of food, especially if it is dry, and partly digests carbohydrates.

This nervous connection in the brain can be considered permanent; it is an unconditioned connection, an inborn reflex present in all individuals of a given animal species. If the brain is sound and intact, this connection functions and this important act, a component of the food instinct, is performed. Only in sickness, for example, fever, the salivary reflex is inhibited and the mouth is dry.

Things are quite different in the case of a temporary, conditioned reflex: its intensity is influenced by the slightest change in the conditions of the experiment or the environment, and its manifestations vary in different individuals. A conditioned reflex can be formed by combining an indifferent stimulus, say the flash of an electric

bulb, with an unconditioned stimulus, for instance, food. In this experiment the stimulation goes from the retina along the afferent nerve to the visual centre in the cerebral hemispheres and a focus of visual excitation is formed in the cells of the visual centre. Since this is accompanied by feeding, another, stronger, focus of excitation is produced in the animal's nervous system, the nervous process being diverted from the weak centre of excitation to the stronger, the dominant one. Gradually, in the course of several days, or even sooner, a *path* between the two centres is *paved*, and a temporary contact, a conditioned salivary reflex (Fig. 16) is formed.

Such interconnections between conditioned and unconditioned reflexes can be observed not only in animals but in children as well. A newborn put into a warm bath for the first time exhibits a negative reaction, it moves its limbs in a haphazard way and cries. Here we have an example of diffuse, motor rather than secretory activity. Crying is an inborn instinctive reaction, the unconditioned defensive reflex evoked by simultaneous excitation of many nervous centres. As time goes on, most infants come to like bathing in warm water and smile on seeing preparations for a bath being made. This is a conditioned reflex. A baby very early begins to react to the warmth of its mother's hands and her caresses; this, too, is a conditioned reflex of very early formation. Sucking, i.e., the satisfaction of the main food instinct, is an unconditioned reflex. Thus man's first conditioned reflexes are also formed on the basis of the inborn ones, i.e., are causally dependent on them.

It has been established that the newborn can distinguish sounds in its surroundings from the first day of its life. Soon the child learns to distinguish the mother's voice from all the others. A child fed artificially will, naturally, develop reflexes that differ from those of one who is nursed by its mother. After several combinations of the optic stimulation with feeding, the former will try

to catch with its mouth the nipple on the bottle, the reaction being stimulated by the sight of the bottle from which it is fed and not just any bottle; when offered food in a different bottle or one differently coloured, the baby will not touch it. Thus from the first days of their lives babies accumulate not only positive conditioned reflexes but also inhibitory reactions correcting the reflexes, which will be dealt with in greater detail below. The appearance of a definite system of positive and negative reactions leads to formation of what is called a vital (dynamic) pattern. A clear example of a pattern in the first days of a baby's life is the baby's reaction to the time of feeding and to the daily routine in general (waking at feeding time). With further development of human beings their behaviour patterns (the exact correlation between positive reflexes of different intensity and inhibitory signals arising at fixed times) become more complex, forming the primary basis for more complex behaviour patterns and habits which will continue to develop all through life and will subsequently give rise to most important working habits.

By utilising Pavlov's classic experiments with the salivary gland physiologists are not only able to study the inborn reactions or instincts and conditioned reactions acquired in childhood, which is very important for the understanding of the mechanism of behaviour, but also to gain new knowledge of the peculiar and increasingly more complex reactions of the nervous system.

Pavlov has furnished incontestable proof that conditioned reflexes are connected with the cerebral hemispheres, that they constitute the material basis of the highest type of connections and take part in the highest psychic functions of man.

If the whole of an animal's cerebral cortex is excised, all previously formed conditioned reflexes, for instance, to sound, light, smell, cutaneous stimuli, with very few exceptions, will disappear, while the unconditioned ones,

the defensive, food and other instincts, connected with the underlying parts, will be preserved. The same phenomena are observed in the rare instances when a child is born without cerebral hemispheres; in this case the child has only instincts and natural reactions such as walking, etc., but cannot form conditioned reflexes.

Thus animals adjust themselves to the external environment by means of temporary, or signalling, reactions, i.e., conditioned reflexes. If a signal gives wrong indications during an experiment, for example, no food appears after the flash of the bulb, the dog ceases to react and saliva is no longer secreted in response to the flashing of the light. The unconditioned stimulus—food—used by itself continues to produce its effect. It can be extinguished only after special training in the course of which very potent conditioned reflexes capable of competing with the inborn reflexes are elaborated. The instincts of rapacious animals, for example, their unconditioned defensive reflexes, weaken in the process of domestication although the rapacious nature of a domesticated animal may under certain conditions come to the fore.

Knowledge of the law which governs elaboration of conditioned reflexes and formation of corresponding temporary connections in the cerebral hemispheres makes it possible to combine any external stimulus with any inborn reaction in the dog and other mammals, with any manifestation of their instincts and, consequently, to govern them. Any temporary connections can be elaborated in the animals' brain on the basis of the food, sex and defensive reflexes alone.

The behaviour of man, however, is governed by entirely different motives, namely, social. Only work, training of definite working, athletic and everyday habits, can re-elaborate the temporary connections in the human brain, divert them into other channels, eliminate the faults of education and develop the fortitude man needs to over-

come the difficulties and temptations he may encounter on his way.

A man's sense of duty, love for a friend, etc., may prompt him not only to refuse food, but even to give up his life. This is because man is a social being for whom, owing to certain training, the interests of the collective prevail over his inborn biological stimuli, although the importance of the latter cannot be contested.

In animals conditioned reflexes are only in rare cases strong enough to resist the unconditioned ones, to suppress the instincts. For example, finding the game a hound brings it to its master instead of eating it in accordance with its instinct.

Natural conditioned reflexes (to the sight and smell of food) acquired at an early age are less subject to change than are artificial reflexes (to the sound of a bell) formed later. They may become inhibited but are never completely lost. The artificial conditioned reflexes acquired in childhood are also very stable. This category includes the physiological bases of the habits inculcated in the kindergarten, namely, personal cleanliness, washing the hands before meals, brushing the teeth, etc. The conditioned reflexes requiring training all through life are such important habits as observing the rational daily routine, bringing to an end the work one has started, etc. The school inculcates still more complex habits based on formation and consolidation of artificial conditioned motor reflexes, i.e., working, athletic, etc.

In the chapter on the second signalling system of the brain we shall show in greater detail how man is affected by his social environment. It is this system that constitutes the physiological substrate of the highest creative activity associated with work, speech, writing, etc. Pavlov's teaching, however, does not reduce social connections and relations, arising in the process of work, to biology, as modern revisionists are doing today. Pavlov himself was against applying the laws derived from study-

ing the functions of animals' brains to the norms of man's social behaviour. The human brain possesses new qualitative peculiarities which must be studied separately, but in order to understand the mechanism of the brain's highest reactions, the study must begin with animals. This is a requirement of the evolutionary theory which has brilliantly justified itself in other aspects of life. Suffice it to say that the expression of sensations, so important in human intercourse, was investigated by Charles Darwin who used the comparative method, i.e., compared the manifestations of emotions in man and mammals.

Only after mastering the theory of the formation of conditioned reflexes which form the basis for all habits, can one start studying the object in which we are mainly interested, i.e., man whose reactions are immeasurably more complex.

* * *

Although there are many methods of studying the behaviour of man and animals, the most exhaustive and at the same time perfectly objective method of investigating the behaviour of man both in everyday life and at work is the conditioned reflex method, historically associated with the names of Sechenov and Pavlov. The temporary connections between the sensory receptors of the eye, ear, skin, etc., and the executive organs (muscles, glands, etc.) are the main prerequisite for the continuous improvement of useful habits, including man's working habits. The development of higher nervous activity is closely associated with the changes in the external environment, both biological and social. It is the latter that determines the qualitative difference of man's reactions from those of even the higher animals.

Developing simultaneously with technology (which in turn is connected with economics), the physiological method makes it possible to establish very close connection between conditioned—acquired—reflexes, the

basis of working habits, and unconditioned reflexes, i.e., the essential needs of the organism, as well as with human emotions, without which any work, particularly creative work, is unthinkable. This method enables us to build on this firm foundation a materialist psychology of work with its own important aims, and to indicate the most rational ways of acquiring the useful habits which are necessary for physical and mental work.

CHAPTER FOUR

INTERNAL INHIBITION OF CONDITIONED REFLEXES

Excitation and Inhibition—Two Aspects of Higher Nervous Activity

The part of Pavlov's theory which treats of inhibition of conditioned reflexes, i.e., elaboration of all sorts of delays and restraints of reactions, which occur in all types of work, is very important for the understanding of man's behaviour at work. The special *internal inhibition* in the brain explains not only the formation but also the *precision* of the body's reactions in using different tools which require caution and dexterity.

The phenomenon of inhibition is very important both physiologically and biologically. The sound or light signal which today announces to an animal that food is near and available may lose its positive meaning tomorrow. It would not be expedient if an animal, or a human being, having once acquired a conditioned reflex, were to act in accordance with it for the rest of their lives, regardless of the changes in their environment. The biological environment, to say nothing of the social, is so variable that what is useful may become harmful, and vice versa. That is why, in addition to excitation, an antagonistic, but equally essential process of internal inhibition must operate in the brain, counteracting and limiting excitation and at the same time exhibiting a peculiar unity with it.

Fig. 17 presents a diagram of a positive (*A*) and inhibitory (*B*, *C*, *D*, *E*) conditioned reflexes.

Experiments in inhibition of temporary nervous connections are conducted in laboratories as follows. Suppose an animal to have an elaborated salivary conditioned reflex to the ringing of a bell, reinforced by feeding. In this instance a definite amount of saliva will be secreted

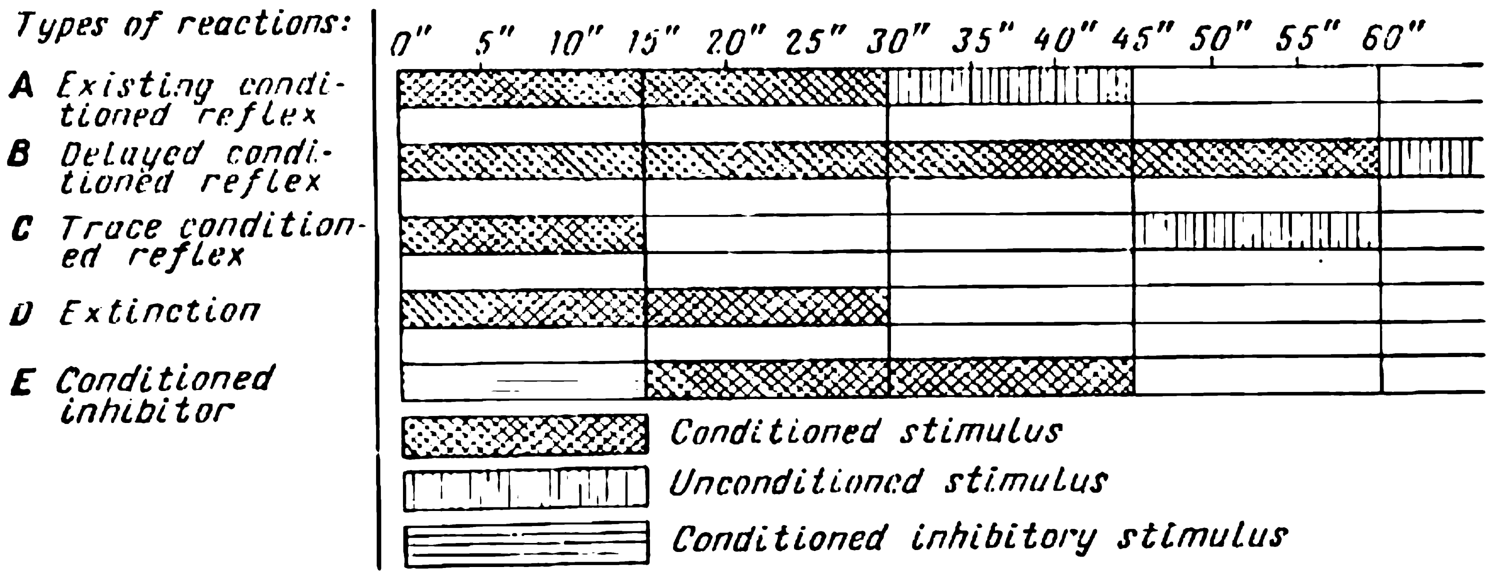

Fig. 17. Diagram of different forms of internal inhibition of conditioned reflexes

in response to the sound stimulant, say, 20 drops during 30 seconds of ringing.

Let us ring the bell several times without feeding the animal; we shall observe the conditioned reflex gradually disappear, become inhibited, become extinct (Fig. 17 *D*): internal inhibition has developed in the cerebral centre controlling the dog's reaction to the ringing.

The internal inhibition obtained in this case in the extinction of the reflex must be distinguished from an external inhibition which is observed, for example, when an extraneous noise is made during the experiment. Such is the effect produced on temporary connections by the orienting reflex—the movement of listening and looking—about which more will be said below. Things are quite different in the case of internal inhibition; the number of

drops of saliva which were to be secreted in response to the sound of the bell does not decrease abruptly but according to a fluctuating curve. The conditioned connection elaborated in the animal's brain but not reinforced by feeding weakens and becomes extinct. Is this perhaps a manifestation of fatigue? If some time is allowed to pass without testing the reflex that is being extinguished, the nervous connection is re-established. Consequently, the elaborated conditioned reflex is not destroyed but is merely temporarily inhibited. It is rather difficult to make such experiments with man, including a quantitative salivary reaction, because of the extreme complexity of the higher nervous activity of adults. At the same time an experiment of this kind can easily be performed with children, and even with adults, by the method of repetition of certain syllables. The curve characterising the extinction of a conditioned reflex in animals and the one showing the gradual fading of the images connected with the memorised syllables in humans are identical, both slowly approaching zero, i.e., total extinction of the given reflex. This shows the unity of physiology and psychology. These sciences indicate that all mental phenomena developing in the process of purposeful work are connected with the work of the highest part of the brain—the cerebral cortex. This is borne out by modern medicine which has established that in mental disorders the first to be affected and disappear are the processes of internal inhibition, as these are the finest and, consequently, the most vulnerable. In this instance, the extinction of the function also fluctuates.

All observations show that in the brain of higher animals and man nervous connections underlying habits not only form anew but also undergo internal inhibition. Clinical tests of conditioned reflexes reveal the defects and disturbances in nervous activity, which occur in the brain as a result of injuries, intoxication and somatic diseases, or the influence of nicotine, alcohol, etc.

The best way to restore an extinguished conditioned reflex is to reinforce it anew with the unconditioned stimulus that had served as the basis for the establishment of the temporary nervous connection. An extinguished conditioned reflex may reappear of itself without reinforcement, merely in virtue of its plasticity. This is particularly true of work where, in addition to the exceptional stability of the reflexes forming the basis of lasting habits of work, we observe extraordinary plasticity of the reflex connections, an ability to reconstruct old and master the new.

Internal inhibition and excitation together regulate all of our behaviour. Although these processes are antagonistic, the dialectics of cerebral activity consists in the fact that these coordinated processes interact in any complex chain of actions. Whereas the formation of a conditioned reflex is based on excitation with the establishment of temporary contacts between two or more nerve cells, internal inhibition serves to sever or temporarily to weaken these contacts. It is the latter circumstance that enables us to control our behaviour, especially under the complex conditions of modern production where each working act undergoes a variety of modifications, which requires particularly thorough training of the process of inhibition.

We have noted above that conditioned reflexes are a higher type of adaptation to the environment because they can be extinguished and restored. Like the establishment of temporary connections, this process operates in conformity with natural laws, depending on external conditions. An associative connection once formed in the cerebral cortex is disrupted under very definite conditions and, if we know these conditions, we can consciously regulate our activity, i.e., our behaviour in physical as well as mental work.

The phenomenon of disrupted temporary connections (including the results of training) has long been known

as forgetfulness. All cases of forgetfulness involve a disruption of contacts, an obliteration of memories, a breach in the chain of associations, particularly in cases of destruction of athletic skills (for example, skating).

We must now consider the question as to which is more important biologically, excitation which makes it possible to establish new conditioned connections or inhibition which removes the unnecessary connections.

Pavlov considered the processes of excitation and inhibition to be *of equal* physiological and biological *value* and always emphasised their *unity*.

"Nervous activity," he wrote, "consists in general of the phenomena of excitation and inhibition. These may be regarded as the two halves of nervous activity. Perhaps there will be no great mistake in saying that they are like positive and negative electricity."*

"... excitation and inhibition," Pavlov stressed, "are but different aspects, different manifestations of the selfsame process."**

While emphasising the common nature of the two processes, Pavlov at the same time noted their antagonism, the fact that normally they are in a state of constant mobile equilibrium, "as though in a struggle". This furnishes proof (in physiology) of the most important law of the materialist theory of knowledge—the unity and conflict of opposites.

Pavlov and his school have devoted a great deal of attention to the problem of the relationship between excitation and internal inhibition, since this problem closely concerns biology, medicine, pedagogics and, of course, cognition of the inner laws governing the process of work.

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* I. P. Pavlov, *Main Principles of the Work of the Cerebral Hemispheres*. Report at the Society of Russian Physicians, St. Petersburg.

** *Ibid.*

Analysers

One of the most important functions of the nervous system is that of analysing objects and phenomena in the outside world. This analysis is effected by the interaction of excitation and inhibition which also occur, although in a more elementary form, in the lower parts of the brain. In order to exist an animal must react differently to different stimuli in the outside world: one stimulus signalises the nearness of food, another, though outwardly resembling the first, may be associated with danger or be indifferent. One stimulus evokes a certain action, another, sometimes closely related to the first, elicits active inhibition. This process is called differentiation, discrimination, or physiological analysis of stimuli; it ensures the organism correct orientation in the external environment.

Elementary perception of objects and phenomena takes place already in the peripheral division of the analysers—in the receptor apparatus of the retina of the eye, the organ of Corti in the ear, etc., where there are various specialised nerve endings for this purpose. But that is not enough for a full and exhaustive analysis of all the phenomena in the surrounding world. This requires the participation of the higher nervous centres. The sense organs are closely connected with the controlling activity of certain parts of the brain which is the organ that really reflects the outside world and directly reacts to it.

Pavlov called the higher centres of smell, hearing and vision "brain endings of the nervous analysers" and attached great importance to them. Science and technology know many analysers, for example, chemical, physical and electrical. According to Pavlov, a nervous analyser is a complex living physiological device consisting of three divisions. It begins on the periphery (the peripheral division) with the sense organ, or to be more precise, with receiving nerve endings, such as the rods and cones of the retina, the hair cells of the organ of Corti, etc., con-

tinues in the afferent nervous paths (the conductive division) which run to the corresponding parts of the brain and ends with a group of nerve cells which form part of a cortical centre (the cerebral or cortical division) such as auditory, visual, etc. This is the third and the most important division of a nervous analyser.

Some analysers serve to distinguish objects at a distance—the light and sound analysers—while others act when the objects are in close proximity—the mechano- and thermo-analysers of the skin and the chemo-analysers. The latter include the taste and smell analysers.

The regulation of man's movements in space (locomotion), the problem that interests us most, depends on the function of the motor analyser. This regulation requiring coordinated action of many groups of muscles, as we saw in studying the act of walking and manual work, is effected in several stages and is controlled at several levels of the central nervous system. The simplest forms of coordination, for instance, between the activity of flexor and extensor muscles of an arm, are effected in the centres situated in the cervical part of the spinal cord. The different postures in work, the positions of the motor organs as well as the "get set" positions of runners at the start are regulated by the centres located in the midbrain (mesencephalon), in the so-called corpora quadrigemina. For especially precise movements required, for instance, in mountain climbing, equilibristics, flights and complex working processes, the cerebellum comes into play. Movements expressing emotions—mostly performed by the facial muscles—have their centres in the subcortex, in the thalamus. But the highest analysis and coordination of motor acts are effected in the cerebral cortex, namely, in its parietal part. The nerve endings of these analysers are dispersed among the muscles of the skeleton and joints. Many kinds of sensory nerve endings also connected with corresponding centres (analysers) in the brain have been discovered in the internal organs—the heart, lungs, stomach, etc.

Thus, the physiological analysis of simple and complex internal and external stimuli takes place in the brain of animals and man, which makes for integrity and completeness of all reactions of the organism. At the same time, the stimuli are united in groups, synthesised, through association. A conditioned reflex, where two stimuli, an unconditioned and a conditioned one, are united, is a form of such synthesis. The analysis of an object is, consequently, inseparably connected with the synthesis of all of its properties and aspects. Man, for instance, is capable not only of distinguishing individual musical tones and semitones (analysis), but also of uniting them, thereby perceiving a continuous melody (synthesis).

The higher the rung of the zoological ladder on which an animal stands, the more perfect the analysis effected in its nervous centres, this activity reaching the highest degree of complexity in man. Synthesis and analysis continuously alternate. Moreover, the frontal areas of the cerebral cortex are very well developed in man and take part in the functions of what is known as the second signal system (see Chapter VI). Thanks to the apparatus of articulate speech here occur the most complex forms of analysis and synthesis, the highest process of abstraction and generalisation, which can be considered the second stage in the reflection and cognition of the world.

Although animals have no faculty of abstract thinking, various complexes are nevertheless formed in their cerebral cortex by numerous elementary stimuli. In such cases not one but several analysers are active. In this way a number of individual well-defined sensations add up to produce the notion of objects, each of which has its shape, colour, quality of surface, taste and smell.

An integrated notion of surrounding objects is the result of coordinated work of a great number of brain cells.

For instance, sunlight that can be decomposed into a series of rays with different wave-lengths, is a very complex physiological stimulus demanding analysis by the eye

and the brain. This analysis is effected by the excitation of some cells of the visual analyser and inhibition of others.

As stimuli, sounds also differ from one another not only in pitch, but in duration and sequence as well. The act of distinguishing between the ascending and descending scales is rather elementary, although it requires some training. A two-year-old child cannot as yet distinguish between an ascending and descending series of a few sounds, but if correctly trained, learns to do it by the age of four. Animals, especially the higher mammals, have a keen sense of hearing and can distinguish between C and C sharp, where the difference is only a semitone, but cannot analyse, differentiate more complex phenomena, for instance, chords. And though man's sense of hearing is less acute than that of animals', he can easily analyse and synthesise sounds, can distinguish between a major and a minor scales and perceive the combination of sounds in a melody; in a word, he has a musical ear.

The ability to distinguish melodies where sounds are arranged in a very complex way is a type of analysis, differentiation of a complex of stimuli, that can be developed, like complex synthesis, through systematic training.

The systematic training of the brain's ability to analyse and synthesise both sounds, colour hues, smells and the body's movements, and the ability to retain what has been achieved for a considerable time form the basis, as we shall see later, of different methods of teaching working and athletic skills which do not consist of separate reflexes that start with stimulation of the receptors located in the contracting skeletal muscles, but of reflex complexes.

Operation of Nervous Processes in the Cerebral Cortex

It has long been known that nervous impulses forming the reflex arc are transmitted along nerve trunks both afferently and efferently.

Pavlov succeeded in establishing the pathways of excitation and inhibition in the mass of the cerebral hemispheres (Fig. 18). How did he do it? We have stated that

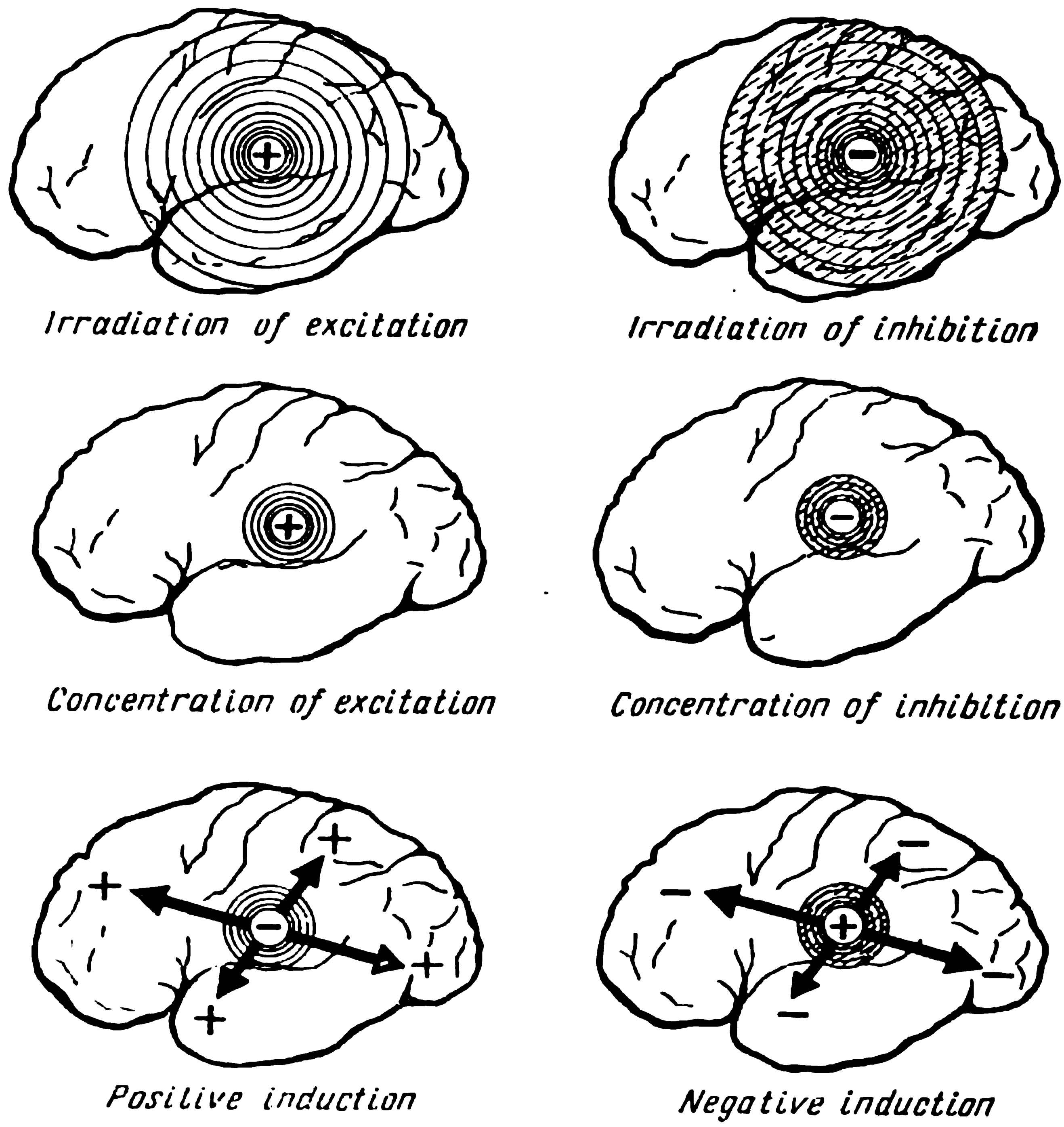


Fig. 18. Operation of nervous processes in the cerebral cortex

temporary or conditioned reflexes become extinguished, inhibited, and disappear when the corresponding stimulus (light, smell, sound) is not reinforced by the unconditioned one, for instance, food. Students of behaviour noticed that simultaneously conditioned reflexes elaborated on the basis

of this unconditioned reflex (for instance, food) also disappear. But conditioned reflexes formed on the basis of another unconditioned reflex are not affected when a temporary connection is disturbed. The inhibition of cerebral centres, consequently, is not confined to one place but spreads over the surface, involving the centres of other conditioned reflexes united by the same biological basis. This prompted the studies of the principal laws governing the operation of nervous processes in the brain, which were not clear prior to Pavlov's researches, although very important for elaborating methods of vocational training. It is precisely in this field, i.e., vocational training, that the complex interaction of excitation and inhibition is observed.

Before Pavlov's investigations teachers were afraid of each act of inhibition. Pavlov proved that internal inhibition can be either harmful or useful, depending on the conditions under which it arises.

In monotonous work inhibition is observed spreading to other points of the cerebral cortex, often very remote, producing a state of indifference, ennui and even sleep. To prevent such diffuse inhibition from interfering with instruction, the lessons must be made interesting. In animals experimental sleep corresponds to human boredom. Since internal inhibition induced by monotonous stimuli is not stationary, but irradiates, spreading to more and more cerebral centres, the animal falls asleep.

Diffuse inhibition must be confined within certain limits. Physiology shows the way to do it: excitation must be more often opposed to inhibition, as is done in the laboratory, when the ability to distinguish between two stimuli (two sounds) is elaborated, with C being reinforced by food and D not being reinforced. In this case irradiation of inhibition will decrease and the animal will be awake, will remain active during the experiment. Hence, the best way to avoid dull lessons and to raise labour productivity is to introduce the element of variety.

Variety in presenting the material, as well as the significance of the material and its relation to practice are what make a lesson interesting.

The constant interaction of the two main aspects of the nervous process—excitation and internal inhibition which operate unceasingly and extend to different centres of the brain—makes for an active state of the worker and helps him to orient himself under the changing conditions of his work. Drivers, for example, very clearly distinguish all shades of red, yellow and green signals. It will be observed that for engine drivers, chauffeurs and fliers it is not only the colour (wave-length) of the signals that is important, but also the complex spatial relationship between them, by which they are guided in the dark. Thus, in these cases, too, analysis is associated with synthesis, discrimination with generalisation. Concentration of excitation and inhibition and their precise interaction, which are particularly clearly manifested in creative work, enable us to react correctly and expediently to one type of stimuli (positive) and abstain from reacting to other stimuli (negative). This is characteristic of the work of an expert in any field.

Are there any limits to the signalling and discriminating activity of the brain in mastering a speciality? In principle there may be no such limits.

The longer we study some object or phenomenon, the more clearly do we see all its aspects, connections and manifestations and the deeper our knowledge of it. Training, however, means not simple repetition or learning by rote, but the establishment of a correct proportion between work and rest and a timely transfer of attention from one object to another.

This idea of the work of the brain is a result of Pavlov's deep penetration into the nature of higher nervous activity of man and animals. The conclusions reached on the basis of laboratory studies of higher mammals by the conditioned reflex method are of equal value for physiolo-

gists and for industrial hygiene because of the decisive role played by the state of the nervous system.

It is well known that proficiency is not attained all at once, that it takes time to acquire skills. What is the reason for this pattern of behaviour? Wherever it arises, excitation, like inhibition, irradiates, spreads over the nerve cells, and the movements, consequently, lack precision; this is characteristic of any novice. American behaviourists call this the "trial and error method". But this is the beginning of elaboration of a skill. Next comes concentration of the two forms of the nervous process. Subsequently a complete delimitation of the activity of the cerebral centres is achieved, including a perfected analysis of the movements of the corresponding muscles. Only after this complex preparation of the nervous centres connected with training does the skill improve and finally reach perfection. That is why one cannot expect to become particularly skilful from the very beginning of vocational training. The expediency of this phenomenon is quite clear, for one cannot know beforehand what combination of movements will prove the most useful to the organism. It is therefore best not to demand quick and precise reactions at the initial stages of training.

It should be remembered that in the process of training excitation and inhibition in the nervous centres are in a kind of struggle, alternately colliding and withdrawing from each other. If this struggle is not directed along the needed course by well thought-out methods, diffuse inhibition gains ascendancy and interest in the lesson or work is lost.

It is now possible to measure the speed with which excitation and inhibition spread through the mass of the cerebral cells and which depends on the state of the nervous system, the strength of the stimulus, the individual properties of the learner and a number of other factors. Inhibition moves through the cerebral centres much more slowly than excitation. When inhibition has spread over the cere-

bral hemispheres, sleep sets in. Pavlov considered sleep to be diffuse inhibition of the cells of the cerebral hemispheres.

What is the physiological state which is directly opposed to diffuse inhibition or sleep? A very strong or prolonged excitation of some point of the central nervous system results in widespread irradiation of excitation. It embraces a great number of cerebral cells, including the motor analyser centres where the motor apparatus—muscles, joints and tendons—is represented. Such a state is usually the result of excessive environmental stimulation, as, for example, in cases of strong emotions, such as rage, joy, etc. This state of the organism, known as affect, often interferes with work. In such a state one must not make any serious decisions, because the internal "brakes"—inhibition, the analysing faculty—are for a time out of order and a rash act may defeat the purpose.

The strength of the stimulus plays an important part in training. Some believe that the stronger the stimulus, for instance, the louder the voice in which a command is given, the better it is obeyed. Actually the nervous system has its limit of excitability. It has been established that stimuli of medium strength are the most effective both in everyday life and in learning a trade, whereas strong stimuli evoke irradiation of excitation which may develop into inhibition. This affects the skills unfavourably, for which reason experienced instructors and superintendents never raise their voices and yet their orders are obeyed more readily than are those given by loud-mouthed people.

Thus a conditioned reflex or a habit can be regarded as formed not when the corresponding temporary connection has been established in the brain, but only when the corresponding excitation has been concentrated, cleansed from all extraneous elements, i.e., collateral reactions.

A high degree of concentration of excitation in a centre where it attracts excitations coming from weaker foci of excitation in the brain is called the *dominant*, or the

predominant focus. Dominants are manifested in the most important instincts; they are observed not only in the laboratory but also in everyday human life, although here they are for the most part determined by social causes.

A. A. Ukhtomsky who suggested the use of this term justly supposed that dominants play an important role in the process of organised work. When all other stimuli yield to the one desire to achieve a certain result, to realise a certain idea, to solve a problem that is equally important for the person in question and for the entire social unit, a very strong focus of excitation is formed in the brain, the conditioned connections are established more easily and the work becomes more purposeful and more efficient. This phenomenon corresponds to expedient orientation of all of one's behaviour in work.

A very important form of regulating the nervous process in the brain, in addition to irradiation and concentration, is nervous *induction*. Induction is a complex interrelation between excitation and inhibition, without which there can be no perceptions or reactions, no working processes, athletic training, or scientific discoveries. It is a true aid in all creative acts.

It should be noted that nervous induction has nothing in common with the induction treated in textbooks of logic or electricity, for it is a perfectly distinct and purely physiological process.

There are positive and negative forms of physiological induction. Positive induction observed in nervous centres during work with conditioned reflexes is manifested in the fact that inhibition arising at one point of the cerebral part of an analyser immediately evokes the opposite process—excitation—at another point (proximal or distal) of the cerebral hemispheres. The intensity of the conditioned reflex to the corresponding conditioned stimulus greatly *increases*.

Positive induction can explain many subjective phenomena. It is manifested in the fact that a weak stimulus

coming directly after a strong one seems weaker than it really is, while a strong stimulus applied after a weak one appears excessive and unendurable. This, incidentally, underlies all the effects of contrast of sensations evoked by stimulation of our sense organs and used in music and painting to produce artistic impressions (contrast between loud and soft sounds, of lights and shadows, etc.).

Negative induction is the case when an elaborated conditioned reflex evokes inhibition in other points (proximal or distal) of the cortex. It is also manifest in forgetfulness which is often observed in old people. While trying to recall one thing old people usually forget other, and perhaps equally important things.

Negative induction is also observed in healthy people who may not be old but who are engaged in pursuits requiring excessive concentration of attention.

Negative nervous induction is one of the causes of accidents, both in industry and in ordinary everyday life, occurring as a result of temporary inhibition of certain occupationally important foci of activity. Well-trained people are, of course, likely to have fewer accidents. Hence, during training (athletic, as well as vocational) excitation and inhibition, and the associated phenomena of irradiation, concentration and induction must alternate so as to ensure their quick and correct localisation in the brain. In the case of transport workers the stimuli, for example, the road signals, must not be in any way frightening.

Another example—a control panel at a power plant or the controls before the pilot in a plane. There is a great number (dozens) of all kinds of measuring instruments to be attended to in these cases, but a well-trained specialist can keep an eye on all of them and react in time to any changes in their readings. The same applies to those who work in communications.

This type of work requiring strenuous attention with thousands of conditioned reflexes taking place in the brain should be performed by an automatic device. The physio-

logical limit to the efficiency of the brain necessitates introduction of electronic cybernetic machines now used on the transport and in communications and industry.

All that has been said of irradiation, concentration and induction forms the physiological basis of the acts of purposeful attention, guaranteeing success in any vital undertaking.

Orienting Reflex—the Physiological Basis of Attention

While the above-described phenomena of higher nervous activity may in a certain way be termed the physiological basis of human attention, science knows another phenomenon which determines the behaviour of our organism under the most trying conditions, as when we find something new in what we have thoroughly studied and think we know well.

The orienting reflex or the reflex to new external stimuli is very important for the physiology of work and for other spheres of higher nervous activity. No purposeful activity, including social activity and work, is possible without taking into consideration the elements of the new and the unexpected that crop up in our lives.

The experiments with dogs in Pavlov's laboratory showed that the formation of any conditioned reflex reaction is accompanied in the initial stage by the appearance of a special type of biological motor reaction which can be described as watchfulness. It is manifested in staring, sniffing, turning the head in the direction of the new stimulus and intense orientation of the animal in general. All these small, but none the less important, movements serve to improve and make more precise the perception of the properties of the new stimulus. This orienting reaction determines the organism's readiness to defend itself or to attack, although the acts themselves may not follow.

Numerous experiments have demonstrated that with the appearance of the orienting reaction the elaborated condi-

tioned reflex weakens. This is the effect of the so-called *external* inhibition of the conditioned reflex connected with the aforesaid negative induction. The stronger the orienting reaction, the more intense the inhibition. This type of inhibition which arises instantly, "on the spot", upon the appearance of a new and unexpected stimulus should be distinguished from the internal or conditioned inhibition, described earlier, which is elaborated gradually, in the course of training.

The following are some examples illustrating the great biological significance of the orienting reflex. Suppose a cat sits for hours awaiting the appearance of a mouse from a small hole. Compare its outwardly motionless concentrated state with the quick, determined leap as it pounces on its prey. The cat manifests an intense orienting reflex for a long time. This reflex is particularly strong in monkeys. If a perfectly innocuous but unfamiliar animal, say, a frog is put into the cage with monkeys, the latter will instantly scatter to hide in corners or up in trees. In this instance orientation is manifested in flight (defensive reaction). Subsequently, when the thing ceases to be new, the monkeys approach the frog, begin to touch it and may kill it while playing.

The orienting reflex can be observed in man, its manifestation being the stronger, the younger the individual.

Attention based on the orienting reflex plays a very important role in the elaboration of different skills. Prolonged concentration on one object leads to lowered efficiency. On the other hand, an abrupt change of objects and the appearance of unexpected strong stimuli also produce an unfavourable effect by evoking defensive inhibition which protects the nerve cells from harm.

Children display much livelier attention to what is new than do adults who react to "sensations" with greater restraint. In the process of training it is important to remember that the orienting consists of two phases. The moment attention is drawn to something, albeit the most

important thing, the momentary attention necessarily impedes the manifestation of the conditioned reflex, disturbs the habit formed and lowers labour productivity (negative induction). However, this should not disconcert anybody, for such is the physiological effect of every orientation or adaptation to the change in the environment, to the new course of events.

Soon (in cases of proper training) this negative phase is followed by the other phase, the one during which we investigate the new object or phenomenon. Incidentally, a certain element of novelty should be—and always is—present in any reaction, however well we may have penetrated into the essence of the subject, or have become accustomed to it. Complete automation of occupational behaviour is therefore impossible; nor is it necessary.

The orienting reflex described by Pavlov is the physiological basis of constant interest in the object or phenomenon under investigation, which it is important to emphasise in connection with vocational training. The physiological processes operating in the brain during manifestation of the orienting reflex lie at the basis of involuntary attention.

The orienting reflex differs from conditioned reflexes in that, appearing as a *first* reaction, it disappears when repeatedly evoked, while conditioned reflexes, repeatedly evoked and reinforced by unconditioned reflexes, become more stable.

As the result of the orienting reflex, involuntary attention is manifested in professional life in the aforesaid two phases. The first, like negative induction, can be the cause of accidents and of lapses in the training process of study, harmful from the practical standpoint. A person who for the first time in his life finds himself on the premises of a factory or shop may be so astounded by the novelty of his surroundings as to stand open-mouthed (inhibition of contraction of the masticatory muscles), literally dumbfounded, and in danger of serious injury. But after a few

months' work in the shop the novice feels very much at home. By carefully studying his machine, his production line, the process of work as a whole, he can become an innovator and a fine worker, especially if he takes a course of theoretical training while continuing to work.

Despite the acts of involuntary attention connected with the orienting reflex, however, in man the decisive role is played by the mind, the activity of the second signal system of the brain, on which voluntary attention is based. Every act of attention should be *organised* and subordinated to the influence of the cerebral cortex, for which purpose the knowledges and skills must be acquired in a strict sequence. Special mention should be made of examples of so-called distributed or combined attention when, having mastered his vocation, a person can perform several complex reflex acts *simultaneously*, for example, attend to his machine, study the blueprint and supervise the work of his helper.

Trace Conditioned Reflex—Foundation of Memory

Sizing up the situation and maintaining attention are prerequisites of success. The concept of trace conditioned reflexes (Fig. 17 C) is also very important for understanding the work processes and for the theory and practice of vocational training. We deal with memory already when elaborating the ordinary salivary reflex. Without traces retained in the higher cerebral centres and in the analysers it would be impossible to establish connections, to combine conditioned and unconditioned stimuli, to acquire experience and utilise previous experience. Let us start our study of the basis of memory, as always, with a live model, a laboratory experiment on the complex phenomena in the brain. The physiological methods of studying memory in animals are as follows: the dog is given a signal, for instance, contact with its skin, which is followed by an interval of from 15 to 30 seconds (sometimes even up to

3 minutes); only after the expiration of this time is the conditioned stimulus reinforced by feeding. During the interval internal inhibition sets in in the cerebral centres. For the animal this is a very difficult type of internal inhibition. A trace reflex is elaborated much more slowly than usual conditioned reflexes. The beginning of the conditioned salivary reflex coming as a rule directly after the signal (the tactile sensation) is shifted in cases of trace reflexes closer to the moment of feeding. The first phase of excitation of the nervous centres is actively inhibited and a struggle between excitation and inhibition takes place in the brain. Depending on the type of its nervous system, the animal sometimes goes to sleep (irradiation of inhibition) during the interval and sometimes becomes extremely agitated. There is no doubt that the process of delaying the positive conditioned reflex reaction proves a strain on it. Dogs can barely endure inhibition lasting so long, and conditioned trace reflexes are hard to elaborate even in monkeys. If stimulation is not suspended during the interval but is continued without reinforcement, it somewhat relieves the situation, although some strain remains just the same.

The same difficulty is encountered with children when they are made to wait for a promised treat, for instance, sweets. The grown-up has to be firm, or there will be no end to the child's pleadings and whimpering. Yet trace reflexes are elaborated in children more easily than in animals and here the time lapse between the unconditioned and conditioned stimulus may be as long as 15-30 minutes.

The process of teaching many trades requiring close attention in expectation of events that do not happen immediately (waiting for signals by the man on duty at a power plant or at some other responsible job) involves elaboration of lasting trace conditioned reflexes. There are cases in which not only seconds and minutes, but hours, weeks and even years pass between the time the order is received and that of its execution and yet the reactions

are faultless just the same. The seemingly interminable interval in activity makes some people feel ill at ease and produces the so-called "anxiety neurosis". Recall the tense atmosphere that is felt in an auditorium when an actor on the stage purposely makes a pause for psychological effect.

Trace conditioned reflexes, like conditioned inhibitions about which more will be said in due course, can—as ordinary reflexes—become extinguished, reconstructed and differentiated, all these processes operating with greater difficulty than in experiments with usual conditioned stimuli. Vocational activity is for the most part based on trace conditioned reflex reactions regularly occurring in the brain.

The concept of acquired trace reactions and of their role in human behaviour can best be illustrated by the elaboration of the *time reflexes*. Superintendents and organisers of production processes must remember that precisely trace conditioned reflexes underlie the sense of time estimation developed by, say, a turner in the process of his work, form the chief foundation of the correct working rhythm, as well as of self-control, and are a prerequisite for increasing labour productivity.

Whereas the elaboration of precise ideas of space, for instance, estimation of distances by sight, is achieved through combining signals coming to the brain from the organ of sight, from the organs of equilibrium in the internal ear perceiving the movements of the head and, lastly, from the moving muscles of the eye and the skeleton, physiological estimation of time in the organism is a more complex phenomenon. Our bodies have no special time measuring organ. The elementary count of time, the reproduction of the elementary rhythms of the day and night, is connected with the property of the nerve cells and cerebral centres to change in conformity with the signals from the rhythmically functioning organs, such as the heart and the respiratory and digestive systems. The measurement of

time is effected by changes in the intensity of metabolism in all nerve cells and takes place rhythmically (for example, the alternation of day and night). Such crude units for measuring time are inadequate for occupational purposes, although they are very helpful in everyday life. There are some people who go to sleep at night and can wake up at a definite (accustomed) hour, even at a precise minute, without an alarm clock. Particularly precise in measuring time are the cells of the higher part of the nervous system, especially those that are trained daily, as in sprinters and fliers, who are accustomed to measure their reactions by hundredth and thousandth fractions of a second.

In industry reactions to average time are also essential. When we study animals' reactions to time by the method of conditioned reflexes, for instance, by feeding a dog every ten minutes, the dog shows the conditioned reflex only in the ninth minute. But if food is given now after 5 minutes and again after 9, the dog reacts in the seventh minute, showing a fine adaptation to the complex rhythm of the events, the alternation of excitation and rest. One gets the impression that in the nervous system there is a mechanism measuring time better than any timepiece. This peculiar count of time is the manifestation of very complex physical and chemical processes occurring in the intricately constructed nervous tissue, an indication of the rhythmic alternation of the expenditure and replenishment of the substance in the higher centres of the brain, although the lower centres also assist orientation in time.

Special devices have revealed the ability of transport workers, especially highly trained specialists, such as modern airmen, to determine time precisely. The human brain is an organ capable of the highest and finest methods of measuring time and space, it is at the same time an analyser of the speed of movements which are so essential in work and are closely connected with planning work, both individual and collective.

These observations of higher nervous activity suggest the following conclusion: systematic training of the sense of time, as well as of other faculties, ensures high labour efficiency.

Conditioned Inhibitors

A living organism constantly encounters situations in which its nervous system must alter all its reactions to meet the suddenly emerging new conditions. The selfsame stimulus may acquire a new, entirely different meaning if an additional external agent is added to it.

A conditioned inhibitor (Fig. 17 *E*) is elaborated in the laboratory in the following way: say, an animal has a conditioned reflex to the sound of an electric bell, each time reinforced by feeding. As soon as this reflex has definitely formed the flash of an electric bulb is added to the bell, and this *combination* of stimuli is *never* reinforced. After this combination of stimuli has been used several times the animal's reflex will weaken and become extinguished precisely in those cases in which the light *precedes* the sound of the bell, whereas the sound alone, accompanied by feeding, will preserve its positive effect. The lamp has evidently acquired a definite special meaning for the nervous system, it has become a conditioned inhibitor to the bell reflex. The inhibitory action of the light is clear from the fact that all other conditioned reflexes (smells, touches, etc.), formed on the basis of the same unconditioned reflex (food), have begun to be inhibited by the flashing of the bulb: *if* this latter precedes any of them, *then* saliva is not secreted. Other conditioned reflexes, for instance, to acid, remain effective. We shall have more to do with this "if-then" formula associated with conditioned transition (Chapter IX).

A negative conditioned reflex can be elaborated also in another way.

If some conditioned stimulus (light) is being extinguished

and a neutral stimulus, say, beats of a metronome, is made to act on the sense organs, the metronome beats will themselves evoke internal inhibition in the animal's brain.

To explain the delimitative role of the conditioned inhibitor, Pavlov compared this phenomenon to an article of law which is accompanied by several notes qualifying it and making it valid only in very definite cases, for example, varying the penalty with the circumstances of the crime, and thus rendering more precise the rules governing man's social behaviour.

* * *

It is clear from the above that work, particularly mental work, cannot be investigated without a simultaneous study of the functions of the brain in their continuous development and evolution.

Physiologists and hygienists can study behaviour directly connected with work by Pavlov's conditioned reflex method, as well as other methods, such as the anatomical, histological, biochemical, electrophysiological and, lastly, psychological, since the last named method is also based on data of the physiology of the brain and the sense organs.

Pavlov and his school discovered the main regularities in higher nervous activity directed at satisfying the organism's numerous needs in experiments with higher animals. These regularities include the phenomena of formation of temporary connections, the most important phenomena of various forms of inhibition, and the dynamics of the nervous processes characteristic of the more complex occupational acts. The physiological analysis of the phenomena of professional memory, attention, fatigue and restoration observed in the work of nerve cells is a reliable basis for further study of the main nervous regulators of working processes in their complex aspects, observable

only in human society and requiring knowledge of the functions not only of the first, but also of the second signal system, inherent in man alone.

All skills, all useful associations, connections and working habits are formed in the organism by means of conditioned reflexes of varying complexity, through the excitation and connections of different centres in the brain. However, Pavlovian physiology teaches that all this is not enough. In addition to the law of temporary coupling in the cerebral hemispheres there is also internal inhibition. The two phenomena form a single whole.

It is not enough to elaborate a useful skill, to effect a connection by means of reinforcement. The work of the brain's functional analysers, of the higher nervous centres, is directed towards cleansing the nervous connection that has been formed from all extraneous elements which are unavoidable in the beginning, owing to irradiation of excitation. All that has formed through irradiation and has not been confirmed by subsequent practice, i.e., all that does not satisfy the organism's vital needs, must be discarded, for nothing must clutter up the higher parts of the nervous system.

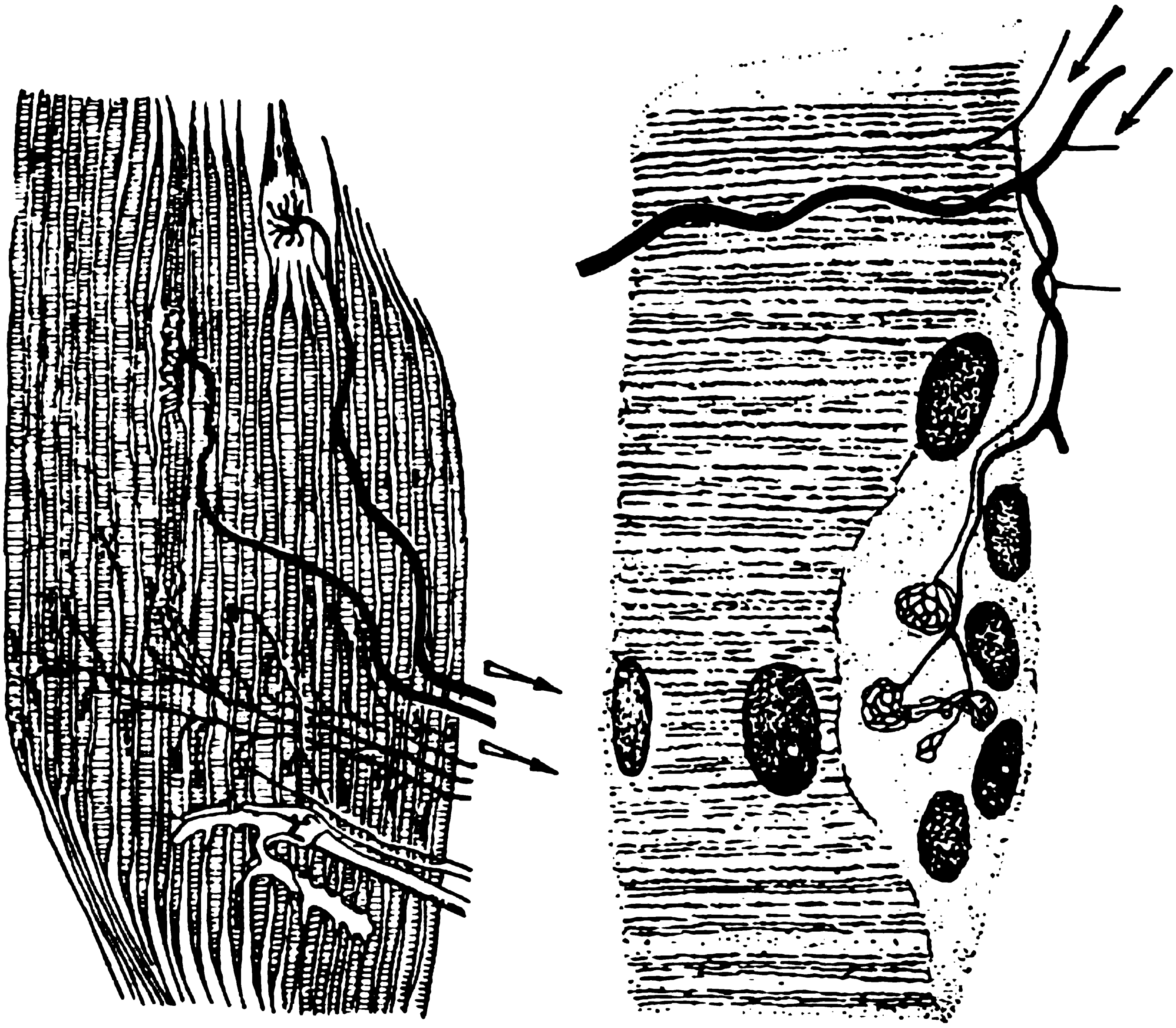
CHAPTER FIVE

HIGHER NERVOUS ACTIVITY AND ACQUISITION OF SKILLS

Muscles—Chief Source of Conditioned Reflexes

We have repeatedly pointed out that a muscle is at once a receptive and executive organ participating in each work act.

Now we must consider how man's complex orientation in space is achieved with the assistance of the muscle sense and how it is connected with higher nervous activity. It has long been known that, in addition to the five external sense organs, man has a complex sense for orientation in space; it plays an important part in all of life's manifestations—travelling, work and sports. We have also repeatedly mentioned its sources, i.e., primarily the organs of equilibrium (the vestibular apparatus and the semicircular canals in the internal ear), the muscles of the eyes and the skeleton, from which signals pertaining to the position of the body in space go to the brain, etc. To estimate the direction of movement in practical life we use various physical instruments. The compass and range finder invented several centuries ago are, naturally, more precise than the elementary space sense. Yet our own organs, the eyes in the first place, are our indispensable "devices", our first reliable orientators.



A B

Fig. 19. Nerve endings in muscles. *A*—peripheral receptors of muscle and joint sense; *B*—motor nerve endings in muscle

Most of our actions and locomotion in space are controlled by the eye. But we know that blind people can play the piano and other instruments. Many sightless persons work at factories often performing rather complicated operations, as for example, assembling small motors. An experienced sorter's fingers themselves seem to find the defects in the parts without the help of the eyes. The same is observed in textile and many other workers who perform complicated manual operations. All such movements are complex temporary connections elaborated in

the course of life on the basis of tactile and muscular sensations.

The corresponding receptors of the muscular sensation (nerve endings) are located within the muscle (Fig. 19) and in the synovial membrane which lines the articular capsule where the bones are in close contact with each other. When a muscle contracts, it sends signals to the brain, and the stronger the contractions, the more intense the afferent signals. Owing to the gradual improvement of these signals by training, man can effect any combination of muscular contractions even with his eyes closed, control them and, consequently, improve the quality of his work. Exact estimation of the direction and speed of each movement of the head, trunk and extremities is also essential in all athletics and sports, writing, drawing and painting—in any exercise or art. Together with the eye, the muscle sense of the arm and hand enables us to establish precise distance relationships between objects. This sense underlies the work of designers and the inventions of various instruments, facilitating in turn the orientation among physical phenomena and objects.

The role of muscle sense was emphasised by Sechenov in his speech in commemoration of the physiologist Helmholtz.

Sechenov pointed out that man looking at an object may be said to be "feeling it" with his eyes; he not only perceives the mutual relation of the different points on its surface but reaches with his "visual feelers" into the depth, works with them in the third dimension, and determines the distance. All this takes place provided the two eyes work in accord, with the visual axes converging on the object viewed. In this way a clear idea of the object's relief and perspective is formed. This occurs because from the contracting eye muscles during the convergence and the contracting muscle which changes the convexity of the crystalline lens during accommodation the afferent nerve impulses reach the corresponding cerebral centres.

Combining according to the laws of temporary connections, the signals are transformed into efferent, into orders to act. Such reflexes connected with the auxiliary—muscular—apparatus of the eye, like the reflexes from the skeletal muscles, are called *proprioceptive*.

As Sechenov said in the above-quoted speech: "While the organ of vision may be likened in its effect to contractile tentacles supplied with a visual apparatus, the hand as the organ of touch needs no simile." This suggests that Sechenov regarded the role of the afferent impulses coming from the working hand which handles objects of daily use and work tools, and employs them in processing different materials, as obvious.

Thus, the eye and the hand with their proprioceptive reflexes taking part in the working processes are most intimately connected with each other, the eye directing the hand and the latter, by producing work tools, providing stimuli for developing the cognitive function of the eye. From the first days of an individual's life an interdependence is established between them, constantly improved and made more precise in the course of life, owing to the elaboration of increasingly new conditioned motor reflexes formed during all manner of vocational training.

The tremendous importance of proprioception, i.e., the perception of impulses coming from the skeletal muscles and the muscles of the eye, emphasised by Sechenov, was not fully appreciated until the beginning of the twentieth century. In his "Integrative Action of the Nervous System" C. Sherrington, the British physiologist, propounded the "theory of the common field". According to this theory, the number of impulses, perceptions coming from the periphery to the nervous system, is much greater than the number of "orders" issuing from it. In this way, the streams of impulses coming from the muscles, on reaching the nervous centres, fight, as it were, for the way leading to the muscular apparatus, the impulses which are more important at the given moment winning. This fight gives

rise to the highly organised (integrated) activity of the whole organism, its behaviour in general.

In subsequent decades science began to show increasingly greater appreciation of the afferent impulses coming from working muscles. Basing himself on Sechenov's ideas, the talented Soviet physiologist A. F. Samoilov in his *Role of the Muscles in Our Knowledge of Nature* not only referred to muscles as teachers and trainers of all other sense organs but also said that the dominance of the mechanistic interpretation of nature, which reduces all phenomena of the outside world to mechanical movement, i.e., movement in space (for instance, mechanicism of the 18th century), can be explained by the fact that of all physical phenomena, pushing and lifting weights appear the most comprehensible to us owing to the perceptions coming from the corresponding muscles.

How was the existence of the proprioceptive conditioned motor reflexes established? This experiment was performed in Pavlov's laboratory in 1908 by his collaborator N. Krasnogorsky. A dog's hind paw was held in a starch splint to which a cord running through a pulley was attached. The animal was standing as usual in a stand and was fed from a mechanical feeder. At first the paw was made to swing slightly, i.e., it moved passively; 30 seconds later the dog was given food. For some time the dog did not react to the forced movement of its paw, but as time went on and the movement continued to be reinforced by feeding, saliva began to appear from the fistula, which meant that a food reflex was formed. This was substantiated by the fact that salivation ceased as soon as the reinforcement with food was discontinued. The temporary connection between the change in the position of the paw (its movement in the joint) and the salivary centre was thus demonstrated. This made it possible to draw a number of conclusions of importance for the theory of behaviour. Some time later the dog, with its paw no longer in the splint, began to move the paw of its own accord, the act

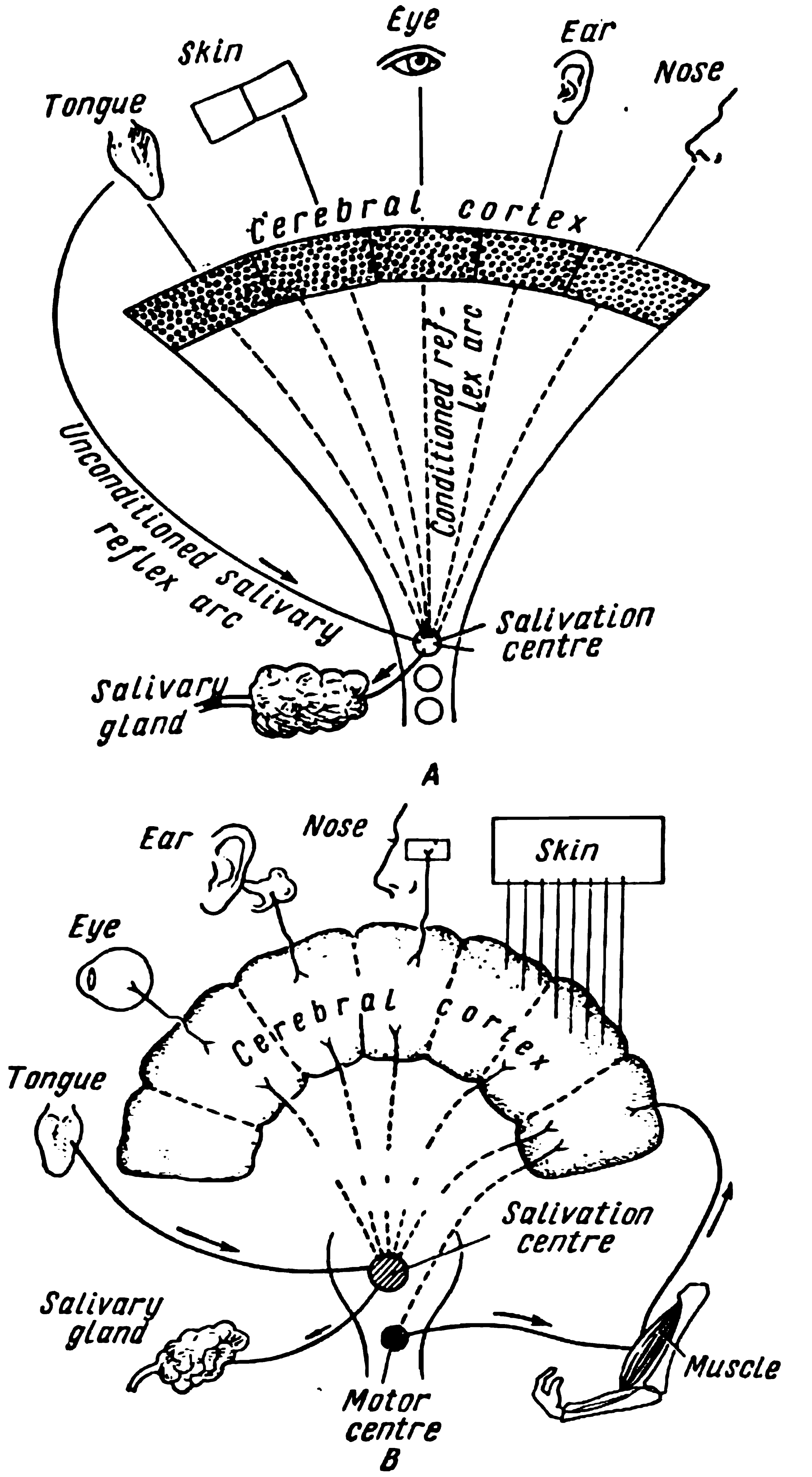


Fig. 20. A—diagram showing mechanism of elaboration of conditioned salivary reflex (after I. Pavlov); B—same diagram supplemented with proprioception and elaboration of stimulus-response connections

being accompanied by abundant salivation. Pavlov's works offer a classic scheme of the formation of conditioned reflexes (Fig. 20*A*). The development of the theory of analysers has enabled us to supplement it with proprioceptive reflexes (Fig. 20*B*).

Learning to Use Work Tools

We are particularly interested in voluntary movements connected with learning to use work tools.

Sometimes human work is called object activity. This is Marx's definition of it. But what does it mean?

Work is not only a biologically expedient movement; from a form of activity it constantly passes into a form of being. The result of work is always a new object or product. Hence the term "object activity".

At the same time work, according to Marx, is not limited to producing objects of consumption; the important thing is that man creates means and instruments of work. The primitive tools produced at the dawn of human history were used to produce increasingly new instruments and appliances to them. In this sense work is inherent only in historical man, animals, including the higher mammals, being incapable of work.

The experiment of W. Köhler where apes used a stick as a lever is no proof to the contrary. At the circus one can see monkeys at the wheel of a motor car, but they are incapable of mending a most primitive mechanism or changing a tyre.

Apes are capable of activity outwardly resembling work because of their highly developed first signal system and complex kinesthesis (muscle sense). But nobody has ever seen a chimpanzee or a gorilla use a stone to manufacture a more perfect tool, for instance, to shape a flint, split a bone or bore in it a hole to make a crude needle for sewing skins, as did primitive man.

Animals can only react to the outside world but cannot change it. A complex adaptive act, or rather a series of purposeful acts that become a form of being ("object acts") can be performed only through consciousness whose material basis is the second signal system of the brain. The latter is inherent only in the social, consequently, the historical man, and will be discussed in Chapter VI.

The initial, prehistoric stage in the evolution of work is associated with the perfection of the upper extremities in the Primates, the Pithecanthropus and others.

In the process of work, objects and work tools made by primitive man began to impart to the environment a new and, if we may say so, humanised appearance. People, unlike animals, not only adapted themselves to nature, but remade it in the interests of their human existence. Speech as the basis of social consciousness was born in the course of human social labour activity.

The right arm and hand of most modern people are better developed than the left. Although some researchers assert that monkeys and apes are dextral, while others observe this asymmetry even in dogs and mice, the prevailing development of the right hand constitutes a generally accepted peculiarity of man, and we will dwell on it at some length as this is connected with work.

The difference in strength between our right and left arms acting through corresponding nervous connections of the muscles results in greater strength of the muscles of the right leg and, generally, in dominance of the right part of the body, which we find in historic man but do not observe in the higher anthropoids.

The predominant development of the right part of the body gives rise to various everyday common occurrences, for instance, the deviation to the left of persons who lose their way in a forest or who walk blindfold. This is because the right foot, better developed than the left, involuntarily pushes off the ground with greater force; in

the case of left-handed persons their left feet predominate in walking and they will swerve to the right. Knowledge of this facilitates control of one's individual faults in spatial orientation.

How has dextrality originated?

The collective way of life and the mastery of work tools, which played the determining role in the development of society, were also responsible for the differentiation in the functions of the hands, the predominance of the right hand.

We may well suppose that primitive man, for whom a stone axe was the weapon of both defence and attack, protected with his bent left arm the heart that is situated asymmetrically, while in the right hand he held a spear, an axe or some other weapon. This habit spread to other aspects of his activity and in working he usually held the material with his left hand, the right performing more important active movements.

The centres governing the movements of the right hand are situated in the left part of the brain and vice versa. This is borne out by experiments on animals and by clinical (neurological) practice. If a man is wounded or has a haemorrhage in the left part of his brain, he loses the use of his right hand and foot. Simultaneously he loses speech and the ability to write, the centres of which are located in the left part of the brain. If a pathological process affects the right hemisphere the person cannot move his left hand but can speak, read and write, which, of course, considerably eases the situation.

Most children are born right-handed (95-98 per cent of the population), but there is no reason for alarm if a baby is born left-handed, for this asymmetry can be corrected at an early age. The experience of nurseries and kindergartens shows, however, that left-handed children should not be urged to change their habits as this may affect their speech. Life among other children, first at

the nursery and later at school, will gradually teach a left-handed child to use his right hand.

The best thing for anyone, however, is to learn to work equally well with both hands. The ability to use both hands alike, so important for a surgeon, for instance, is known as *ambidexterity*.

A few words about the relationship between the human hand and the chief work tools modelled after the hand in the remote past.

Pre-Marxian sociologists, such as Noire (*Instruments of Work*) and others, tended to derive all tools from their organic basis. This latter they saw in the "tooth formula" of animals and man where there are incisors, canines and molars, each group having its own functions: the canine teeth are for tearing, the incisors for cutting and the molars for grinding the food. According to these writers, all existing tools are built after these prototypes.

Actually the tools of the historical man, to say nothing of modern complex instruments of work, are incomparably more varied and complex than the "tooth formula".

From the very beginning of his social development man, in addition to tearing, cutting and grinding, made extensive use of beating (in shaping stones), pressure (with the use of levers), weaving and heating (use of fire), which all are alien to animals and which gave rise to the immense variety of modern work movements (see Chapter VI).

Owing to the development of consciousness and the second signal system on which it is based, the work tools created by man are being *constantly perfected*, dismembered and combined with other tools by a special process of transferring the formerly elaborated conditioned reflexes and skills from one tool to another. This in turn leads to further development of the human brain, the perfection of its functions which find their expression in the work tools. We must attach particular importance to

the understanding of the leap that was achieved in human nature with the appearance of articulated speech and work, the two decisive factors in the development of abstract thinking.

We are laying special emphasis on this important circumstance because recent achievements of electronics and other branches of technology have enabled engineers to construct work tools that can supplant not only the hand but, to a certain extent, attention, memory and other higher functions of the brain (see Chapter IX).

Possible Methods of Training Skills

The sources of origin and methods of elaborating vocational and other skills are extremely varied. Their analysis is an important although insufficiently studied problem of labour physiology. Instructors of vocational training do not always take into account the data furnished by the studies of higher nervous activity, which would make the methods of instruction they use much more effective.

Even students of physiology of exercise, who deal with man's natural movements elaborated over a period of centuries, have until recently paid little attention to the qualitative differences in the various complexes of movements, the conditioned reflexes involved, and the complex interrelations between them, characteristic of individual types of sport.

Some physiologists studying the process of vocational training sometimes gathered the impression that these skills were formed like conditioned salivary and motor reflexes, i.e., through the reinforcement by an unconditioned reflex. But actually this process is much more intricate.

In elaborating athletic skills the stimulus is a desire to set or break one's record. In elaborating vocational

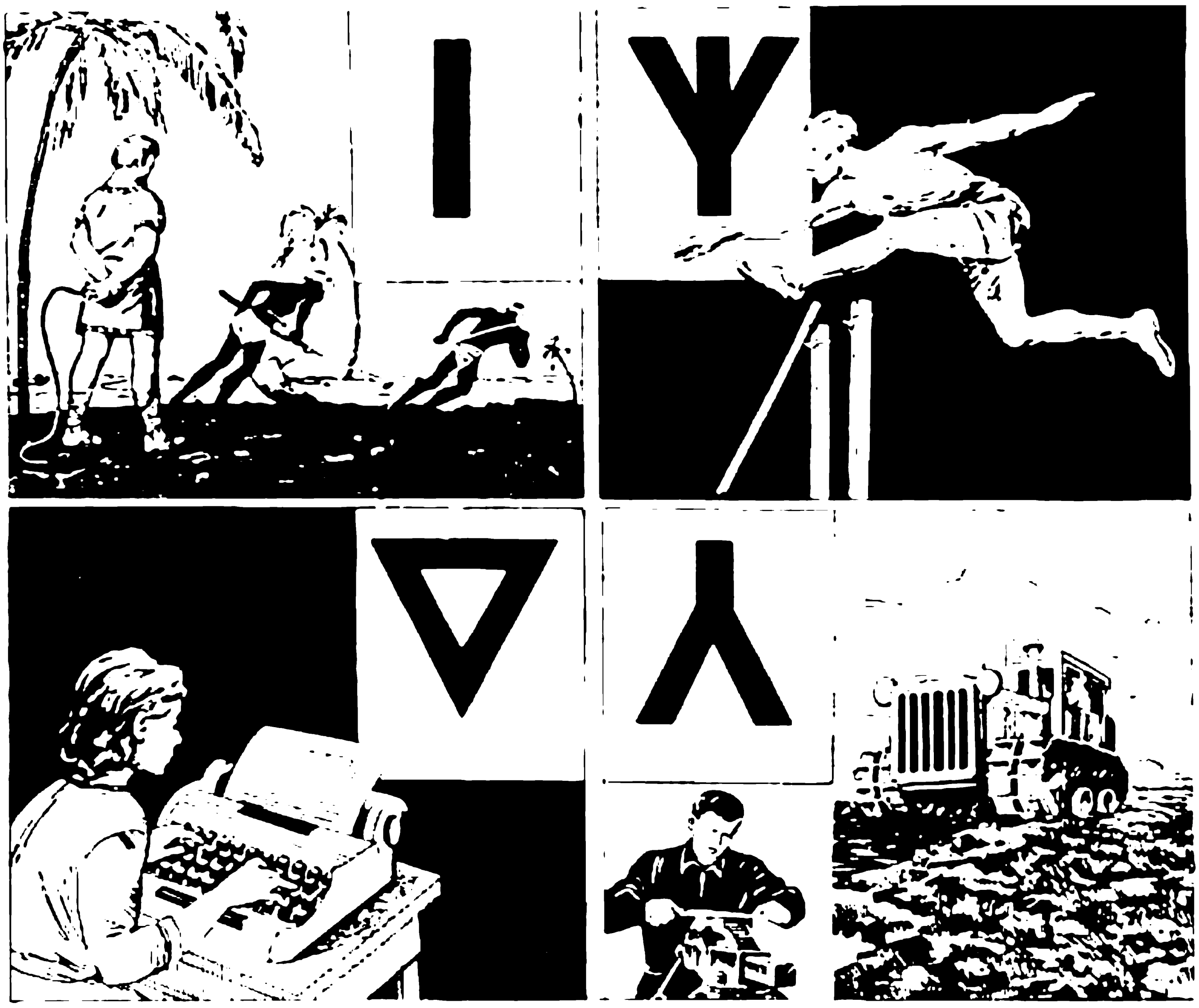


Fig. 21. Main mechanisms of formation of motor habits, as complex proprioceptive conditioned reflexes in man

skills in people who manipulate many different objects, i.e., work tools, the physiological scheme according to which the conditioned motor reflexes and skills are formed is still more complex.

There are four basic methods of instruction (Fig. 21). For the conditioned motor reflex of the simplest type that can be observed in animals we suggest the designation of linear temporary connection, or simple motor association, which connects a conditioned signal with an unconditioned one according to the law of force: the process spreads from the less excited to the more excited centre (the law of the dominant).

Of course, this method can be used to elaborate the simplest work skills connected with manipulation of elementary work tools. That is how work skills were elaborated in the past when work was considered disgraceful. It was used under the slave-owning system, when galley slaves were punished for every wrong movement. To be sure, the slave-holding society produced its own culture, but it paid too exorbitant a price for it. This method is far from offering a solution for the complicated problem of training vocational skills.

The second method of elaborating motor skills is more complex and is connected with the aforementioned irradiation of excitation which arises in the brain when the latter receives signals from any sense organ, including the organs of muscle sense, in performing an important work movement, whether correct or incorrect. Once arisen, this excitation spreads over the mass of the neighbouring nerve elements of the motor analyser, resulting in a number of different, sometimes haphazard, tentative movements in different directions. The rules allow even well-trained athletes to make two or three attempts in jumping contests. In cases of intensive irradiation, especially in children, sometimes chaotic, mutually exclusive movements are observed. This also happens in a state of affect. In the process of vocational training proper skills are not learned all at once, but only after a series of unsuccessful attempts during which more precise movements are gradually developed. This precision is reached, as already stated, owing to the afferent signals coming from the motor organs to the motor analyser of the brain (return afferentation). Thus every attempt may be said to be appraised by practice, the result of the attempt being either preserved or discarded. The "trial and error" method takes too much of the pupils' time and cannot be regarded as a wholly scientific method of elaborating skills.

The third method, used frequently enough and characteristic mostly of old, prescientific pedagogics, is the introduction of a new stimulus between two old ones, elaborated previously on the basis of some unconditioned reflex.

The method of introducing intermediate links was popular when people were taught to read by syllables (before the phonetic method was adopted). It will be noted that 200 years ago learning to read Russian took up *three years*, whereas now this is done in *three months*. It stands to reason that this method was condemned by history.

Not all methods that appear spontaneously in the field of vocational training are good. This should always be remembered if the best of all possible methods are to be chosen.

The fourth method of establishing connections in complex movements (work or higher athletic skills) is known as transfer of training. It is intimately connected with the conditioned inhibition we have mentioned above. This method is widely used in pedagogical practice and in vocational training, in handling complicated work tools where everything depends on the conditions under which the particular skill is used.

To understand the peculiarities of acquiring skills by this method we must remember that every movement itself contains elements of reinforcement, owing to the phenomenon of return afferentation. Every movement is trained by consolidation of the natural movements developed in the course of man's evolution, which is self-evident.

Conditioned motor reflexes, like the ordinary salivary reflex, can be of the first, second, third, etc., order. So far we have dealt with the reflexes of the first order, but besides these reflexes based on unconditioned reflexes or instincts, there are also such temporary connections which are reinforced by well-developed conditioned reflexes.

Such connections are conditioned reflexes of the second and higher orders (not to be confused with the reflexes of the second signal system of which more will be said in due course). New skills are elaborated for the most part on the basis of previously well-elaborated temporary motor connections. As already mentioned, complex movements performed in work and sports are but rarely directly reinforced by unconditioned stimuli. The modern school and modern vocational training do not deal with the elementary "stimulus-response" bonds which underlie the theory of the American behaviourists who are also interested in the processes of vocational training. On the other hand, those who advocate work and training "by inspiration", i.e., without any rules, are also wrong. This problem is of fundamental importance in the Soviet Union where, with the introduction of an extensive programme of polytechnical training, acquisition of various work skills must not be of industrial but of educational significance and at the same time must maintain close connections with the social practices.

Most frequently we observe the formation of a conditioned reflex on the basis of another conditioned reflex, i.e., deal with a chain of reflexes of the second order. This takes place, for instance, with a novice who begins to handle a hammer, a saw or a plane, or is learning the trade of fitter or turner. The work skills acquired on one kind of material form the basis for increasingly new methods of work with another and more complex material. Very important in teaching skills is speech, the word of the instructor who points out the aims of the assignments and explains the methods by which they may be fulfilled.

We have stated that any conditioned motor reflex of the second order can be based on a previously elaborated reflex of the first order. Pavlov's teaching shows, however, that for purposes of successful vocational training a teacher or instructor should be very careful in superimposing one conditioned reflex on another because of the

many albeit surmountable difficulties encountered in such cases.

The fact is that each new stage in the development of reflexes, in this case motor reflexes, can, depending on the relative stability of the underlying ("supporting") stimulus, the stability of the reflex that has been elaborated, and certain other factors, either become a conditioned reflex of a *higher* order or an inhibition. When a skill becomes structurally more complex, the single chain of motor acts stretches, or the secondarily joining stimulus becomes a conditioned inhibitor, depending on its strength and certain other qualities. This stands to reason, for the secondary stimulus is never reinforced, or else we should have a reflex to a mere sum of consecutive stimuli, which is not our aim. Sometimes, if increasingly new skills are acquired, become prematurely complicated, the whole vertical chain of connections is inhibited and the skill is destroyed. Irradiation of inhibition develops in the pupil's brain and a "blank spot" is formed. The pupil ceases to understand what the instructor wants and loses interest in his work, whereas interest is the most important thing.

Conditioned motor reflexes should be superimposed on each other by transfer of training circumspectly and cautiously. An example of such transfer of training is a person who is able to drive a motor car and learns to sail a motor boat after two or three trips. This is because the new type of activity contains many elements of the old activity. Of course, this transfer is still more effective where the trainee is aware of the similarities and differences between the old and new skills. Only when a reflex of a higher order (second, third, etc.) has been finally elaborated can it be directed towards a new stimulus, another action, which can then be combined with beneficial results. Only prudence is likely to lead to such rapid acquisition of skills as is observed in well-organised polytechnical training.

It should be noted that in *all* cases of formation of stable skills the course of the nervous process ceases to be a linear function and becomes closed, cyclic. A peculiar structure of the reflex arc is the result, the conditioned connection working in *both directions*. For instance, in walking the end of each motor act (step) excites the motor centre of the opposite hemisphere and the result is the next motor act—the step of the other foot. According to Pavlov, direct and return afferentation underlies all voluntary actions of man. This is an important inference for vocational training. One more thing to remember: in transfer of training, every new link of an established skill of a higher order is usually based not on one but on two or three firm "supports"—motor reflexes (skills) of a lower order, and this is precisely the basis of stability of a skill. As we shall see later this requirement is confirmed by the entire history of technical culture, in this lies the meaning of the transfer of training which is so important for polytechnical training.

The secret of success of the most talented and experienced teachers and instructors of general and vocational training lies in their ability systematically to transfer the connection-forming process from one object to another with its subsequent consolidation on previously formed skills and utilisation of return afferentations. On the other hand, cramming the selfsame thing down the pupils' throats (according to the stimulus-response scheme), can lead only to tedium and even repugnance in the pupils.

How do the methods of training used in human practice differ from the similar methods employed in elaborating skills in the animal kingdom?

The most important difference consists in the use of *speech* at all stages of instruction by instructors or more experienced friends. An instructor's speech is addressed to his pupils' second signal system which is governed by laws that somewhat differ from those governing the first system, the system of direct signals from reality. However

backward a pupil, even a beginner may be, he always wants to know the *reason* for using this or that method or instrument, sets himself an immediate *task* or a long-range *objective*, seeks to get satisfaction from his work and solves some problem, trifling as it may seem.

Physiological Role of Emotions in Vocational Training

What has been said about the mechanism of elaboration of useful work skills does not relax our attention to the basis of all perfection, the biological and social roots of the *interest* revealed in work. We mean the emotional basis of work itself, the positive effect this social need of man produces on the health and well-being of the working people, in a word, all that underlies the physical, as well as moral, well-being of the socio-historical man who is creating material values.

Even highly mechanised, completely automated work does not preclude an emotional attitude to it. On the one hand, highly developed technology, telemechanics, radar and other modern achievements require a particularly keen sense of responsibility for one's every movement. On the other hand, the question of what should be mechanised and how it should be mechanised is connected with the prospects of the entire social economy and, consequently, is also of emotional interest. With the development of technology this feeling must grow and expand in all working people. In addition to the technical factor, the behaviour of the working people also includes a moral factor. The problem of the relationship between absorbing work and the desire to make it easier is approached from the premise that work contains a deeply emotional element. Sports and amateur art activities which attract a great number of people are also connected with work as a means of cognising reality, of serving the collective aims that are increasingly coming to the foreground along with the continuously developing social relations.

It should not be supposed that the problem of facilitating work and, consequently, that of labour hygiene is solved only by making physical work less strenuous and by removing from the nervous system the strain of mental operations. Work involves not only the nervous and muscular systems, but also the whole of the organism, including the internal organs—the heart, lungs, endocrine glands, etc. The *vegetative nervous system* which regulates all the processes of metabolism, including those connected with work, plays a particularly important role in this. Positive emotions stimulate the vegetative nervous system and create favourable conditions for the functioning of the whole organism. This leads to lesser fatigue and greater efficiency.

The positive effect produced on a worker by his interest in the results and aims of his work, as well as by his participation in the collective effort of the people who work in the same rhythm, is elucidated by studies in the physiology of exercise and athletic emotions, feelings that grip one's whole being.

It is no accident that in an age of increasing automation on the transport, in communications and industry, at a time apparently requiring a minimum of physical effort, sports (football, volleyball, etc.) should attract more and more working people—an unprecedented occurrence with the exception of perhaps certain folk games.

The football, basketball, aquatic and winter sports fans find themselves in the grip of emotions which serve to mobilise the highest physical efficiency.

The emotional state of the participants in the games results in an increase of sugar and adrenalin in their blood, which enhances their endurance. Through conditioned visual reflex the content of these substances increases also in the blood of the spectators during the tensest moments of the game. The contest arouses the emotions of tens of thousands of people watching it from the grand-stands.

This shows that emotional excitement favours mobilisation of the organism's powers.

Positive emotions enhance the organism's potentialities and raise efficiency not only in sports but also in work. A particularly important role is played by the lofty social emotions observed in the emulation and mutual assistance of the Soviet working people, and in the work of the Communist Work Teams.

Dynamic Pattern of Behaviour and the Importance of Changing the Patterns in the Physiology of Labour

If we abstract ourselves from the emotional element in work, the whole complex of working operations will appear as a series of links or chains of reflexes making up well-elaborated habits or skills. These chains are not fixed once and for all, however, but are mobile, like all properties of a living organism.

In order to form a clear idea of the mechanism of such complex phenomena as working, athletic and behaviour reactions in general, which is very important for a teacher, trainer and work superintendent, we shall consider the Pavlovian concept of the *dynamic pattern*. A dynamic pattern is a phenomenon in the nervous system, in which a complex series of several reactions to several external stimuli is effected.

Here is an example. Salivary reflexes have been elaborated in a dog to several stimuli in the following sequence: to the sound of a bell, to light, to smell, etc. Each of the stimuli was accompanied by feeding, and to each the dog reacted with a certain amount of saliva in keeping with the physiological law of force, sound causing the most abundant salivation, light—less, etc. This yielded a series of magnitudes of conditioned reflexes, which could be observed from day to day. All the stimuli were united in a chain of associations (connections), the reaction to the

first stimulus preparing the organism to perceive the second stimulus, etc. Such is the pattern of the secretory reaction. If instead of the salivary reactions we observe the movements (as in the case of elaborating skills) we will have a chain of consecutive movements. This is the manifestation of a conditioned reflex (motor) pattern.

If the pattern is well elaborated (for instance, there are four successive conditioned reflexes), it will suffice to apply one stimulus (e.g., light) at all points where other stimuli were used for the animal to show the same picture of salivation it showed every day, although there will be no other conditioned or unconditioned stimuli except light. Some of the "links" of the chain may be of the nature of elaborated inhibitions, that is, negative conditioned reflexes or "prohibitions".

We see that the application of one of the stimuli evokes the whole chain of the conditioned reflexes in a definite sequence and rhythm. The intensity of the reflexes will show that the various stimuli have been synthesised in the dog's brain to form a complex pattern and that a system of reactions has been established.

Every physical exercise and every occupational skill are definite motor patterns, with certain motor centres being excited, others inhibited, the excitation and inhibition changing places, etc.

It is not so easy to form such reflex chains in animals, but once formed, they are difficult to alter. In man, on the other hand, any pattern can be elaborated and eliminated, corrected and modified, and separate "links" can be differentiated and their sequence changed, if there is any need for it. Here is where conscious interest, characteristic of man, comes into play.

If we consider from this viewpoint an ordinary lesson in physical training, say, a lesson of swimming (without going into technicalities) we will always encounter some complex dynamic pattern. The same applies to a series of lessons at which some useful skill is mastered, as, for

example, in an athletic school. Training means the consolidation and perfection of motor patterns, as, for instance, learning the three R's.

It is wrong to begin a lesson with difficult exercises and then do easy ones for the rest of the time. The accepted order of a lesson is such as to ensure gradualness in the work of the nervous system which is best suited to systematically alternating complex stimuli. In this adults markedly differ from children. Children find it hard to adjust themselves to sharply changing patterns, while monotony tires and bores them. The skill of a teacher or instructor consists in preserving the pattern elaborated by previous exercises and at the same time endlessly diversifying it. In the U.S.S.R. this is done in the field of physical culture, for instance, during the morning exercises over the radio, in which a pattern is strictly adhered to, although some of the exercises are from time to time replaced.

The nervous system encounters particular difficulties when a pattern has to be *completely* changed. In the laboratory this is done by substituting negative stimuli for all the positive ones, and vice versa. This causes in animals general chaotic excitation or diffuse inhibition—sleep. This may occur in cases of imposing excessive demands on the brain, i.e., fatiguing it. Pavlov called the state caused by overstrain of the nervous system a nervous breakdown. The higher parts of the brain can bear neither monotonous strain nor frequent changes of patterns. At the same time, the basis of controlling fatigue consists precisely in systematic changes from dynamic patterns of work to those of rest.

Take rhythmic movements to music, for example, dancing. They are less fatiguing than ordinary movements without music. If the nervous system is bolstered up by a ready-made rhythm, as is the case in dancing, fatigue does not soon set in.

In a set of physical exercises, as in any other type of

human activity, variety, along with a fixed system, is the best means of controlling fatigue.

In connection with the physiology of patterns it is necessary to broach the problem of the health-building and hardening influence of physical culture as a means of increasing the vitality of the organism, as well as that of controlling fatigue by the introduction of short periods of setting-up exercises during working hours.

Physical culture strengthens the whole organism. It improves the functioning of the internal organs and enhances the organism's resistance to disease.

Setting-up exercises being introduced in shops, offices, higher schools and other Soviet institutions have both their ardent advocates and opponents. Some of the latter hold that physical exercises during the working hours confuse and distract the workers, etc.

However, the increase in labour productivity as a result of the short periods of setting-up exercises has led to their almost general acceptance. This is easy to explain from the physiological point of view, since these exercises are a form of active recreation. Besides, the alternation of work and recreation patterns itself becomes a pattern, the workers get used to it if, like other useful measures, for instance, ventilation, good lighting, etc., it is part of the system and has become fixed in their brains.

It should be noted that change from one system of instruction to another (for example, introduction of polytechnical training in the school), introduction of new technology, etc., also involve a change in the established patterns. All innovation, rationalisation and invention also require modification of the established behaviour patterns.

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Thus physiology attests that, in addition to the well-known external sense organs, there is also a muscle sense, the sense of movement or locomotion, which plays a very

important part in everyday life, work and sports, as well as in elaboration of all kinds of skills in various fields of human activity.

New motor reflexes arise on the basis of old ones previously well fixed by practice.

Pavlov's experiments with animals have shown that all motor habits, without exception, acquired in the process of forming any pattern are conditioned reflexes, temporary connections in which the decisive role is played by the motor analyser of the brain located in front of the central sulcus. Owing to the precise signalling of all muscular contractions taking place during the movement of bones and rotation of the joints, and in virtue of the stimulus-response connections, the motor analyser selects the most suitable movements which answer the purpose and do the work most economically as regards the given skill. All unsuitable and inexpedient movements become inhibited and discarded by the process of inner inhibition. However, this is but one of the many possible methods of elaborating useful human skills, used in the process of training in the school and in industry.

There are several ways of making the pupil fulfil his assignment. Knowledge of the laws governing the formation of new work skills is particularly important for polytechnical training and is the basis for scientifically organised industrial hygiene.

The most rational method of elaborating practical skills is *transferring* the conditioned reflexes elaborated on a firm basis with the handling of a definite group of work tools to other groups of movements used with other work tools (transfer of training).

The concept of the dynamic pattern changing consistently and regularly together with the changes in the work tools and with the improvement of conditions of work and training is the most important concept of the physiology of the brain and is very valuable for training in work skills.

CHAPTER SIX

SECOND SIGNAL SYSTEM AND CREATIVE WORK

Speech, Counting and Writing as Second Signals of Reality

Man is distinguished from animals by his mind which manifests itself in his social behaviour. At the same time his reactions to the environment are, like all other natural phenomena, governed by the strict laws of causality.

What constitutes the objective difference of man's behaviour from that of animals? Human cognition is not limited to sensory impressions and direct perceptions of objects, of which animals are also capable; it is on a higher level determined by man's ability to work, speak and think.

Human thinking is manifested in certain forms of behaviour which are called conscious. Our concepts of the physiological laws of development of thinking are based on Pavlov's teachings on conditioned reflexes and on his conception of the first and second signal systems of the brain.

The beginning of thinking is closely associated with sensation, sensory perception of surrounding reality. The human sense organs function according to the same rules as do those of animals: in both cases there is perception of objects and phenomena of the real world, adaptation to the environment, formation of a series of conditioned

reflexes which directly reflect the world, retention of traces of former stimulations, etc.

Synthetic concepts of the objects of the surrounding world are formed in the animal's brain from the signals transmitted by the different sense organs. An example of this is the complex *relationship* between the perception of the physical and chemical properties which constitute the biological essence of the olfactory conditioned alimentary reflex or detection of some object or human being by the sense of smell. Consequently, the animals' first signal system is capable of reacting to relationships of objects, since animals have no second signal system.

The same applies to the relationship of alternation of objects and phenomena in time, to estimation of the number of concrete objects and of their distance in time and space.

In discussing conditioned reflex connections we have already repeatedly based ourselves on the activity of salivary glands. In man this secretory reaction can be evoked not only by the usual stimuli, such as light, smell, etc., but also by means of the word (saliva is secreted at the word "lemon"), which is a conditioned reflex manifestation of the second signal system.

In the process of his development, mainly in the process of social labour, man's brain evolved from the formation of concrete images to that of notions, thoughts and abstract ideas of the external world.

Abstract thinking of which only man is capable takes the form of generalisation of all sensory material, of abstraction from the concrete properties of individual objects and phenomena. Moreover, in his work man always seeks the laws of causality and sets himself conscious aims, which is not the case in the animal world. As Marx said, "What distinguishes the worst architect from the best of bees is this, that the architect raises his structure in imagination before he erects it in reality"*.

* K. Marx, *Capital*, Vol. I, Moscow 1961, p. 178.

So complex a phenomenon as thinking must have a corresponding material nervous structure and its new function which arose and developed in the brain of the historical man at a fairly high stage in the evolution of human society. And this is the second signal system (Pavlov).

The process of meditating in abstract ideas is intimately connected with the word as a social factor, with the complex apparatus of speech. The importance of the word for the development of human society cannot be overestimated. It gives expression to every phenomenon of the surrounding world and, more important still, generalises the multitude of homogeneous objects and phenomena. The word "horse", for example, designates a definite animal, but at the same time it generalises a big group of animals, often very dissimilar (a heavy-draft horse, trotter, etc.), and conveys an abstract idea of what is common to all of them—quadruped, herbivorous, mammalian, etc. All such words and ideas are the result of abstraction from less important qualities, such as the colour of the animal's coat, etc.

Speech is the most important acquisition historical man has made in the process of collective labour.

The appearance of the word offered a basis for abstract thinking with work and the complex relations deriving from it as the subject. Work also created the prerequisites for the maturing of science in close contact with practice.

Abstract thinking and speech are inseparably connected, and are together dependent on the activity of the highest part of the central nervous system which receives the complex signals of reality's signals, that is, the words of articulate speech.

Language is a means of fixing and transmitting thoughts to other members of society, consequently, it involves an extraordinary expansion of memory, which in language loses its individual character and becomes the memory of a tribe.

Language makes possible an *exchange* of ideas in human society and is thus a potent means of information and communication which with the development of society become increasingly more complex.

Pavlov said: "If our sensations and notions caused by the surrounding world are for us the first signals of reality, concrete signals, then speech ... constitutes a second set of signals, the signals of signals ... this constitutes our extra, *specially human, higher mentality*, creating an empiricism general to all men and then, in the end, science, the instrument of the higher orientation of man in the surrounding world and in himself."*

By the "specially human, higher mentality" Pavlov means the second signal system, i.e., speech, drawing, writing and counting.

By his theory of the signal systems Pavlov mapped out and physiologicaly substantiated the materialist idea of the social-labour origin of human consciousness, which had long before been expressed by the classics of Marxism.

"Cognition," we read in Lenin's *Philosophical Notebooks*, "is the eternal, endless approximation of thought to the object. The *reflection* of nature in man's thought must be understood not 'lifelessly', not 'abstractly', *not devoid of movement*, ... the arising of contradictions and their solution."**

These are precisely the inner contradictions that characterise the activity of the brain's second signal system.

The new physiological mechanisms of the second signal system raise us above the immediate facts furnished by experience, with which higher animals operate. Consciousness makes the behaviour of man creative and this creative property, born in work, finds its expression in most complicated acts which favour an increasing transformation of the environment. At the same time the creative property

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* I. P. Pavlov, *Selected Works*, Moscow, p. 285.

** V. I. Lenin, *Collected Works*, Vol. 38, Moscow, p. 195.

develops from unconditioned and conditioned reflexes of the first and second signal systems; it is not handed down "from above" and is not a matter of intuition as idealist philosophers believe. Man never loses connection with the biological basis of his behaviour—unconditioned reflexes, instincts—the biological foundation of all reactions. Yet man's behaviour is determined primarily by his social consciousness, social norms and laws, including the demands of the class struggle.

It may in a very general way be said that the second signal system, as the physiological basis of human thinking, fosters the re-shaping of conditioned reflexes of the first signal system and of instincts, which is already observed in the daily life of primitive man. The second signal system of the brain constitutes the physiological basis of consciousness, conscious and volitional acts, i.e., human behaviour as a whole. But the physiological basis of consciousness and consciousness itself are different things. They are not identical, consciousness being but the product of highly organised matter and not matter itself.

The material, anatomic basis of speech and of other higher functions are some of the most important areas of the cerebral cortex where the centres of the second signal system (Fig. 22) are located. They are primarily the frontal, temporal, parietal and, partly, the occipital lobes.

The physiological mechanism of oral speech (Fig. 23) consists in reflex contractions of muscles—movements of the larynx, tongue and lips. Within them lie the organs of the finest muscle sense; these organs have their own analyser in the brain, i.e., in the inferior frontal gyrus. This is the motor speech area. The auditory analyser of speech lies in area 41, i.e., two transverse temporal gyri in the cerebral cortex. In the process of verbal communication, while producing various sounds heard by those around us, we at the same time perceive very fine afferent impulses from the speech apparatus, and auditory signals, the source of which is our articulate speech, divided into

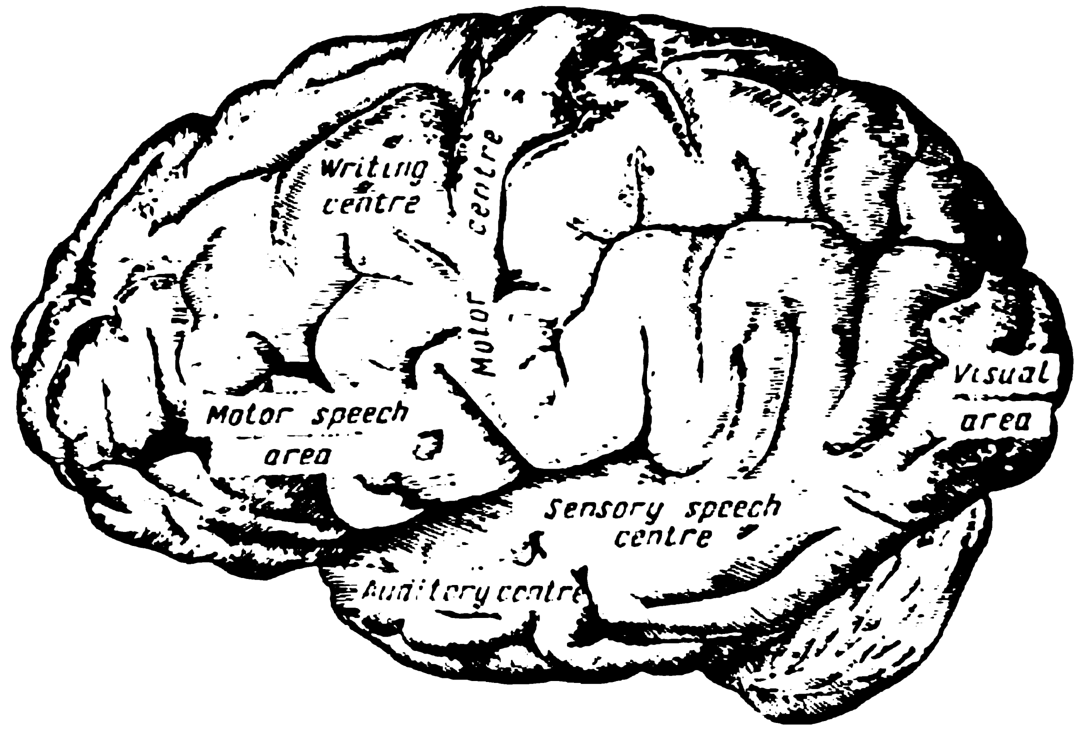

Fig. 22. Localisation of higher centres in the human cerebral cortex (left hemisphere)

syllables by vowels. After perceiving and analysing the sounds produced in the larynx, as well as the muscular sensations of the speech apparatus, we again send impulses to the motor system of the speech apparatus and thus create a stable connection with it, i.e., a typical return afferentation, dominated by a complex physiological rhythm (cyclic rhythm—A. Samoilov).

Although man possesses the prerequisites for the nervous connections of the second signal system from birth (all normal people learn to speak), articulate speech appears at a certain stage of the development of the brain, at the age of one or one and a half years. Simultaneously the child begins to think abstractly because of his association with other people, his desire to tell them something, for instance, to name his parents or his close associates, and in general to establish contacts through speech.

This type of behaviour is inherent only in man. Even apes cannot express any abstract or generalised ideas. Nor is there any abstraction or generalisation of concepts in the imitative "speech" of starlings and parrots; the words

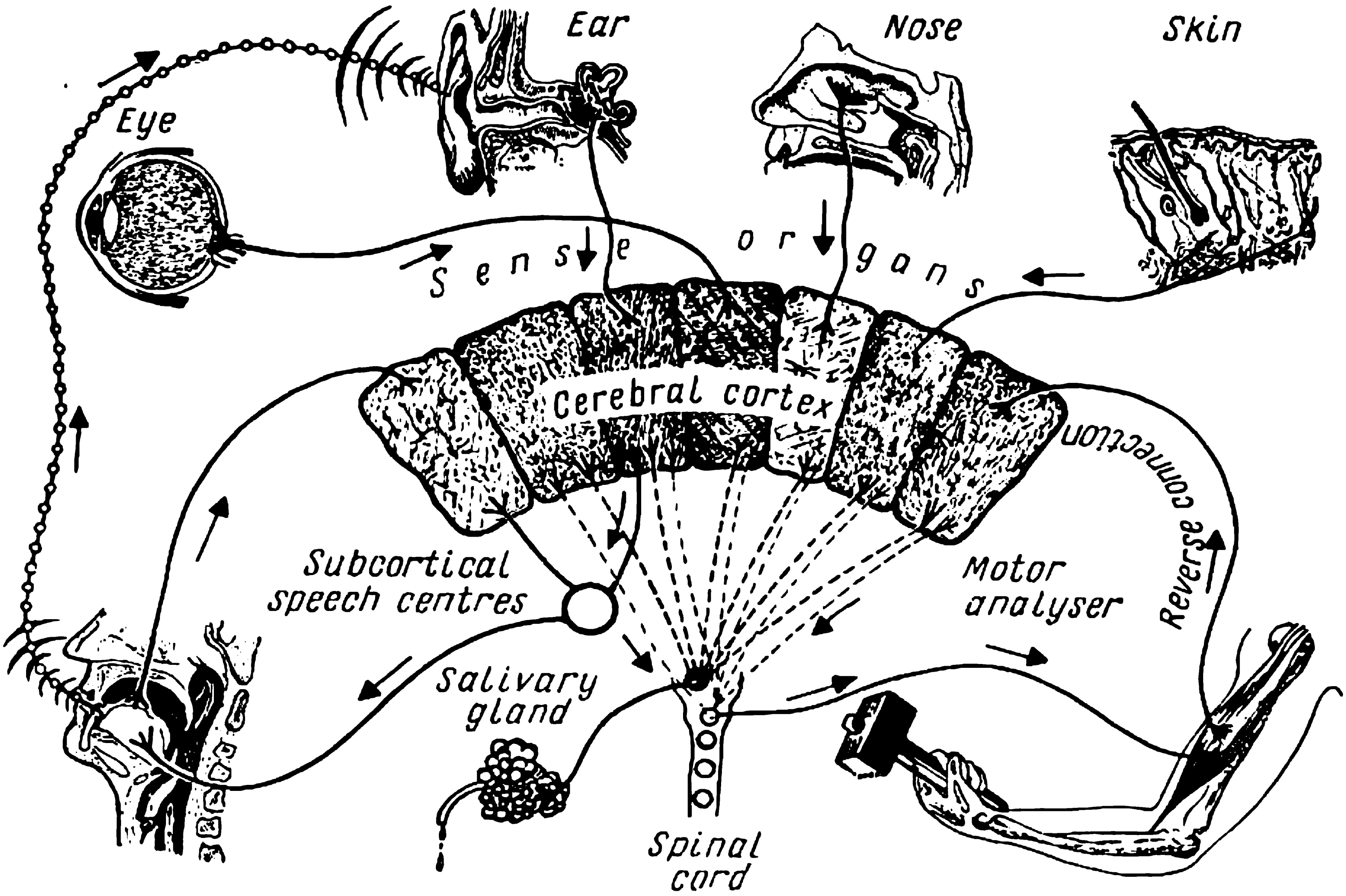

Fig. 23. Conditioned reflexes of first and second signal systems. Stimulus-response connections making speech sounds possible are specially marked

they pronounce are therefore devoid of inner meaning, although they sometimes seem to be uttered aptly.

Thus abstract thinking, the property that distinguishes historic man from animals, begins with the formation of the temporary connections of the second signal system. The organs of speech, which produce the sound of the word, send to the brain minute impulses that participate in the cyclic rhythm of the excitation waves, and at the same time sound complexes are formed, which people who speak the same language perceive as words. As a child grows the cyclic rhythm of his speech expands, drawing into it more and more people around him. The "gift of speech" which at the dawn of human history was accepted

as a "revelation from above" actually issues from society's material requirements, since speech originated and has developed under the conditions of developing social existence.

The complex nature of the corresponding temporary connections, in which so important a part is played by kinesthetic stimuli (going from the muscles), is manifested in the phoneme, a stable sound of speech. A phoneme is a complex physiological phenomenon which is observed in historic man and which has become stable in the course of hundreds of years of language practice of a given people. At the same time it is the simplest element of articulate speech studied by linguists, the speech of both adults and children consisting of phonemes.*

A phoneme is a special audiophonetic reflex, an element of speech, and the object of study of experimental phonetics. A phoneme is quite real and can be recorded by sound-recording apparatus. We speak of the specific "phonemic environment" in which the people who speak the same dialect live. The movements of the speech organs become increasingly more precise and economical until the highest level of adaptation by a people to a language is reached. At the same time it should be remembered that even a well-elaborated phoneme may become inhibited, in which case stammering and other speech disorders develop.

A phoneme is not a simple repetition of the original closing of the reflex arc. Each time it passes through

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* The modern *theory of information*, which has a common basis with the mathematical theory of probability, is studying the phonetic structure of languages with the aim of developing a system of automatic machine translation (mainly of technical texts) from one language into another. These problems are being studied today by Wiener abroad and by Y. D. Panov, Molochnaya, *et al.*, in the U.S.S.R.

Mathematicians have noted the fact that all words in all the languages of the world are in the first place a definite *sequence* of several phonemes. The number of phonemes per word averages eight, from 1 to 16.

the cerebral end of the analyser (the speech centres) it is increasingly purified from all extraneous and additional movements with which it was burdened in the beginning owing to irradiation, induction, etc. This rhythm is repeated thousands and hundreds of thousands of times every day all through the individual's life until the new speech reflex becomes fixed because of the *traces* left after each speech cycle.

Phonemes are created with the participation not only of the speaker, but also of the other members of the "language group". From the standpoint of linguistics, a phoneme is the most elementary formation possessing rudimentary meaning. From the physiological standpoint, it is the *elementary basis* of conditioned reflexes of the second signal system.

In a motor conditioned reflex, such as speech, athletic and work movements, the act of muscular contraction is the beginning of a new reflex link in human intercourse: the result of this action is, in its turn, a stimulus for the next one, etc., i.e., there is a *repeated* reflection of the *cyclic* type.

Several phonemes (usually, two or three) make up a syllable. Several syllables form a word as a basic element of information. It has been established that of approximately 100,000 notional words of a language, only 2,000-2,500 words (including link-words, such as prepositions, pronouns, and conjunctions) are used in spoken and written language.

The reactions of a child from 4 to 9 months old (the period of babbling) revolve in this "circle" of the second signal system, repeatedly passing through the motor analyser of speech—Broca's area—and gradually becoming more perfect as the sounds are freed from superfluous "admixtures". Babbling is not yet intelligent articulate speech, but through it elements of speech are formed, i.e., the phonemes, whose number in all of the world's languages does not exceed 50.

However, the sounds uttered as a means of expressing not only sensations but also abstract ideas are endowed with meaning only when, in addition to the above *internal* cyclic connections effected through Broca's area, other, the *external* cyclic connections are made. This type of connections arises when the child hears its phoneme, i.e., perceives the sound it produces and corrects it in accordance with what it hears from people around it. We emphasise that this sound is heard simultaneously by other members of the child's family or the group of people surrounding it, becomes common property, a means of human communication, in a word, is endowed with meaning as part of their native language. At this instance Wernicke's centre, the auditory centre of speech, comes into play and a temporary connection is established between it and Broca's area. This is the physiological mechanism of the phoneme, the basic element of speech possessing social or semantic significance. At the same time it is a typical reflex of the second signal system (Fig. 23, left).

Proof of the intimate connection existing between the two parts of cyclic proprioceptive reflexes, the internal (motor) and external (auditory), is furnished by the fact that if a child becomes deaf at an early age when the second signal-system reflexes are not sufficiently stable, the child also loses the ability to articulate correctly and, if not properly taught, a deaf child becomes a deaf-mute.

The external, at first family and later, broader, social environment plays a very important part in shaping the cyclic reactions of the second signal system, which form the basis of abstract thinking.

In the course of the development of new forms of human behaviour and social life there appears one more stimulus-response connection of the second signal system, one totally foreign to animals, the so-called *grapheme* which requires participation of *visual* conditioned reflexes. This new type of cyclic connection is the physiological basis of written language. It is located in the brain, in Dejerine's

centre—a group of cells through which passes the arc of the peculiar cyclic rhythm, the physiological basis of written language. The grapheme is a visual-motor reflex, just as the phoneme is an audio-phonetic reflex.

This centre is as inactive (and undeveloped) in illiterate people as the Wernicke centre is in deaf-mutes.

To explain the complex structure of language, we have to differentiate between its *first* element, the phonetic, i.e., connected with sound, which is the *form* of human intercourse, and its *second,* semantic aspect, the meaning (in this case the social significance) of the word. This difference is so essential that phonetically correct speech (for instance, poetry of some symbolist authors) can be devoid of all meaning, while a sentence expressing a profound idea may be phonemically unacceptable, for example, the speech of a well-educated person speaking a foreign language he does not know well enough.

These two aspects of speech—form and meaning—are inseparably and dialectically interconnected. Excessive attention to one of them to the detriment of the other is equally inadmissible.

The word is an obedient tool of thought. In addition to vocabulary each language has its grammar, which connects the individual ideas with each other in compliance with laws specific for each language. An increasingly important part is played by human logic which is associated not only with the word but also with labour, the practice of cognition, the analysis and synthesis of ideas.

The beginning of analysis was made when primitive man cracked a nut with a stone. Each completed work effort requires a cyclic rhythm of excitation in the brain, which is observed in the appearance of the elements of speech. Speech and work are thus interrelated in their very sources, which was emphasised by Engels in his famous *The Part Played by Labour in the Transition from Ape to Man.*

Development of Second Signal System in the Process of Work

Pavlov's principles of the second signal system offer natural science proof of the Marxist thesis that "our consciousness and thinking, however suprasensuous they may seem, are the product of a material, bodily organ, the brain."*

The brilliance of Pavlov's idea of the first and second signal systems consists in the fact that he pointed out specific features of each and showed their foundation—the formation of conditioned reflexes. He provided a materialist solution for the problem of the physiological bases of speech behaviour and showed the way to further research in this important branch of knowledge.

The second signal system appeared about 500,000 years ago (about the time of the Sinanthropus) coincident with the discovery of fire and manufacture of the first work tools.

The chief connections of the second signal system corresponding to speech, counting and writing grew quantitatively and qualitatively parallel with the development of society's productive forces. They were perfected in the iron and bronze ages and continued to improve in the era of steam and electricity. The cerebral functions and the human brain are still improving today. The second signal system is intensively developing in the era of atomic energy and space conquests as evidenced by the emergence of numerous new concepts in various branches of science (quantum physics, chemistry, biology, etc.).

The results of man's planned influence on the environment are in turn controlled by our sensations, i.e., signals from the sense organs (auditory, visual, and from the internal ear and the muscles); this favours development of very powerful return afferentations in the brain of modern

* F. Engels, *Ludwig Feuerbach and the End of Classical German Philosophy*, Moscow 1950, p. 36.

man. Since the productive forces continue to develop and the relations of production change correspondingly, man's abilities to acquire increasingly new abstract ideas also progress.

The anatomical and physiological basis of the second signal system is a product of long evolution. Our vocal and speech organs did not at once reach that level of perfection which enables us to enjoy the performances of singers or actors.

Emerging simultaneously with the improved conditions of life and man's assumption of an upright posture speech considerably modified human life and human nature and provided a new means of human intercourse. The period of transformation and development of speech has not ended as yet.

As Engels aptly pointed out, "... the development of labour necessarily helped to bring the members of society closer together by multiplying cases of mutual support, joint activity.... In short, men in the making arrived at the point where *they had something to say* to one another. The need led to the creation of its organ; by modulation the undeveloped larynx of the ape was slowly but surely transformed for ever more developed modulation, and the organs of the mouth gradually learned to pronounce one articulate letter after another."*

When the historical significance of speech became clear, it was necessary to find its physiological explanation.

Pavlov's correct materialist approach to the physiology of the brain enabled him and his school to reveal many of the most exciting features of behaviour determining man's varied psychic life. They offered a model of strictly scientific methods of treating certain speech disorders. It is particularly important for us today to apply these time-tested principles to the problems of man's behaviour at work and to connect them with man's activity aimed at

* F. Engels, *Dialectics of Nature*, Moscow 1954, p. 232.

remaking the environment, which is no less important than speech, than intercourse by means of speech.

To which of the two signal systems does the act of work belong? Of course, it falls under the second system, but its foundation is laid already in the first.

One of the main reasons that the study of the role of the second signal system in work has somewhat lagged behind that of the other aspects of Pavlovian physiology is the lack of well-elaborated methods of evaluating man's behaviour in work. Until recently there was no reliable method except oral questioning. The investigations were based on the answers to the experimenter's questions. But even children, to say nothing of adults, are likely to introduce into their answers elements of rationalisation and criticism which are not inherent in the first signal system. The differences in the general development and in the command of language of the persons questioned also play a considerable part. Tests of this kind had to be conducted with standard programmes or texts. The standard questions limit the penetration into the second signal system and make the conclusions somewhat superficial. As a result, the physiologist investigating man's higher nervous activity with the aid of standard programmes, often duplicates, in speaking of the second signal system, the data obtained by investigation of the first signal system which is also found in animals, i.e., he biologises man.

That is why Pavlov had the following to say about the study of human behaviour: "I am not enthusiastic about trying all of our canine conditioned reflexes on human beings and think that it can be of little use."* This means that in studying the process of work it is all the more necessary to employ *qualitatively* different methods, bearing well in mind that only the knowledge of man's behaviour in work, in creative effort, can provide a full picture of the unbreakable connection between the mind and the

* *Pavlovian Wednesdays*, Russ. ed., Vol. 2, p. 246.

functions of the second signal system. Human personality develops in children's games and in school studies, but most of all in work, particularly creative work which remakes, changes the environment. We judge of a man as a personality by his ability to create something new. An animal has individuality but no personality.

The development of new forms of society determines the appearance of new laws governing human behaviour in work, as well as in daily and social life. In studying problems relating to the second signal system one must take into consideration the new achievements of technology and the branches of science related to the physiology of higher nervous activity, primarily psychology and the social sciences, and to some extent the latest physics and mathematics that make it possible to study the formerly baffling natural phenomena. Such synthesis of science and technology that will be achieved in the future is envisaged in the works of the classics of Marxism-Leninism, which treat of the great creative role of socially useful work in the development of man and, consequently, in the perfection of his higher cerebral centres in the process of practical activity.

In studying the origin of the second signal system we must proceed from the unquestionable fact that man is a social being who makes tools. This is how Marx and Engels defined the essence of human behaviour. From the physiological point of view this means that with the aid of speech and work man can abstract himself from the direct information furnished to him by his sense organs, his consciousness and second signal system improving on this bases endlessly. This process characterises with utmost completeness the history of development of the second signal system; it is of particular interest for the physiology of work and forms the basis for new practical measures in the organisation and hygiene of working processes.

The ability to abstract oneself from the direct data furnished by one's sense organs is due to the human mind's

power to grasp the most essential, most typical characteristic from among the mass of others, that is, while preserving the most important to abstract oneself from the unimportant, to inhibit the latter and on the basis of the chief and typical characteristics, to define the essence of objects and phenomena and to classify them. Only this faculty, the property of the second signal system, of abstracting from chance characteristics (their internal inhibition), combined with generalisation of phenomena often outwardly dissimilar, but possessing common typical characteristics, enables man correctly to group objects, as when a biologist classifies animals or plants in biological species, genera and orders.

In this way new scientific concepts gradually arise, for instance, *species* and *genus* in zoology and botany, *affinity* in chemistry, *electromagnetic field* in physics, etc. Subsequently, on a higher level of scientific development we master with the aid of dialectical thinking—again through the highest functions of the second signal system of the brain—the essence of such abstract concepts as *space, time, motion, matter,* etc.

Human knowledge proceeds from objective reality, from living experience, to reflection of material reality in concepts, to theory and from theory—to practice. This Marxist-Leninist view of the essence of development of science constitutes, as is well known, the main difference between the philosophy of dialectical materialism (which holds that motion of matter underlies the entire multiformity of nature) and idealism (which regards the idea as primary). Subjective idealists regard consciousness as inner experience and not as a function of the brain which reflects material reality.

There is no need for us once more to enumerate the basic laws discovered by Pavlov as regards the first signal system. Pavlov emphasised their validity also for the second signal system, since in both cases we deal with the activity of the same nervous tissue.

The coupling of a temporary connection, internal and external inhibition, operation (irradiation and concentration) of nervous processes which underlie generalisation of ideas, phenomena of nervous induction (positive and negative)—all these "basic rules" also govern the second signal system, the system of thinking which operates with abstract concepts.

But can the activity of the second signal system be discussed without due reference to the historical influences on human behaviour, without taking into account the gradual development of the specific expressive media connected with the word, counting, drawing and the designing of tools, usually considered to be the domain of the psychology of work? No, it cannot; we must accurately trace the role of this new superstructure formed in the process of collective work and the development of technical skills to understand the complex structure of the human personality.

Pavlov's brilliant idea of the two signal systems of reality constitutes the basis of the materialist teaching on speech and thinking. However, this idea was to be elaborated by later investigators. One of the first problems thus studied is that of the role played by the two systems in human labour activity, namely, what part of the working act is controlled by the first and what part by the second signal system.

What relationship is there between socially useful work and the two systems? What is the role of the techneme in vocational training, both in its simple and complex forms which manifest man's technical and other forms of creative effort?

It should be noted in the first place that the roots of work are to be found in the first signal system, just as the deep roots of speech (phonemes) are to be looked for in the emotional cries of animals communicating signals of danger, calling to each other, etc., all of which are the beginning of future phonemes. The "work-like" activity

of animals living in large families, herds, or "communities", contains rudiments of future technemes as biological elements of behaviour.

A *techneme* is a two-way conditioned motor reflex connected with learning to use the simplest work tools, represented in the higher centres of the cerebral cortex and having its return afferentations. Technemes are the physiological elements of work, which in the course of history become, like phonemes, a means of human intercourse. Museums containing collections of the achievements of material culture are at the same time museums of the creative role played by consciousness that takes shape in work.

Everybody knows what well-articulated speech means, but the notion of correct techneme calls for an explanation.

With training working movements become more regular, more precise and, if one may say so, more beautiful; training thus ensures highly skilful and economical movements of a definite *style*. While the processes of fatigue and restoration of efficiency can be explained by the laws governing the first signal system, style in sports and work belongs to the sphere of conscious labour activity and, consequently, to the nervous processes of the second signal system.

The complex conditioned reflexes, like pressing, hammering, drawing, etc., differ from other proprioceptive reflexes—ordinary and athletic—in that they not only leave traces on some material (wood, metal, etc.), but also reshape this material and create new objects which do not exist as such in nature, that is, create a new material environment which is the product of human labour. Hence it is not simple to tell the signal system to which work belongs. Some of the reactions, i.e., the basic work reactions, undoubtedly belong to the first signal system, although the second system which includes technemes plays the decisive role. Consciousness puts meaning into the

whole of labour behaviour, and consciousness is associated with the work of the second signal system which participates in the remaking of the environment by means of increasingly more complex work tools.

It follows that work, more than any other form of behaviour, is a link between the first and second signal systems and at the same time a powerful means of influencing the first signal system and the whole of man's biological structure.

Work Tools and Corresponding Physiological Functions

Considering the processes of work which characterise the highest manifestations of the activity of the second signal system we must once more emphasise that this system is associated with vigorous social activity typical of man, with the remaking of the environment. By perfecting speech, rationalising and planning social labour, inventing new instruments of production and new forms of organisation of labour, man develops the second signal system and improves its activity. Work in the field of organisation of labour (personal and social) mobilises the vast reserves which are latent in the nervous system and at the same time broadens the concept of the physiology and hygiene of mental work.

The wealth and variety of forms of work in modern society show that the laws governing the second signal system are much more complex than those of the first, which also apply to work, and are becoming increasingly more complex with the developing technology and economics.

It is of paramount interest to physiologists studying the second signal system to determine the influence of various work processes, new materials and work tools on the activity of the human brain.

The same interdependence can often be observed between man-made machines and their parts as between the

functions of the arm and its joints, ligaments and muscles; the structure of the arm seems to serve as a model for the machine. This stands to reason, since the arm and hand are the most ancient "natural tool", the prototype of man-made tools which, in the course of history, have become increasingly more complex. In this way the technemes which we have mentioned before, i.e., the elements of work movements consisting of a series of conditioned stimulus-response motor reflexes, have an equivalent in machines and must, therefore, become the object of study in the history of development of the human brain and the physiology of work.

This likeness becomes particularly apparent when from the arm movements observed in delivering a direct blow—as with a fist or hammer—transition is made to more complex movements such as the rotatory movement involving the use of joints, connected in a chain.

We have mentioned earlier that rotatory movement of the arm can be effected by the shoulder joint alone without connection with any tool. Historically, however, the first rotatory movement was associated with the hand mill, grindstone and potter's wheel which require rotation in the forearm and wrist. In these cases the humerus moves only forward and backward. At first these processes were operated exclusively by hand, the forward movement of the humerus producing through the bones of the forearm and wrist, and their joints, the rotation of the handle of the mill, the grindstone or the wheel gripped with the fingers. But when man wanted to free both hands from turning the handle in order to use them for more efficient work, the feet were made to do the auxiliary work of rotating by means of a treadle which took over the work of the humerus (Fig. 24). It was the prototype of the first link in machines—the rocker arm.

The second link we observe in the grinding or sewing machine is the connecting rod with the forearm as its model. It is connected with the third link—the crank—

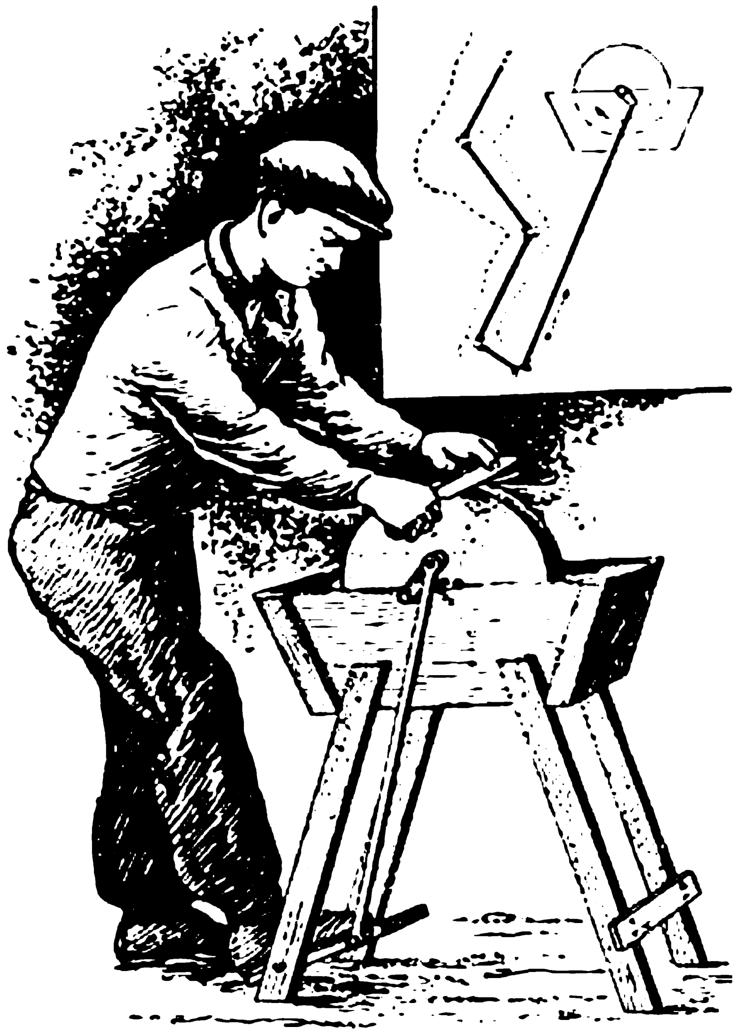

Fig. 24. Transferring arm and hand functions to simple mechanisms (grindstone)

which revolves round an axis, thus turning the wheel of the machine in the needed direction. In length, form and function this part of the machine corresponds to the human hand. The fourth link is the pulley, the only "finger" of the machine; it is the axle on which the wheel is set.

The working movements of the hand are not limited to rotation, but are infinitely varied. In this, too, technology follows the chief model, the human hand. Suffice it to impart a more complex shape and a greater degree of freedom to the fourth link and the machine becomes universal, as the arm and hand within what Sechenov called the "working hemisphere". In the modern machine-building industry this technique is used for constructing the dough-kneading machine, the snow-cleaner, and other appliances with most diverse and practically unlimited forms of movement.

Technicians of the Renaissance constructed their machines on the principle of transformation of translational motion into rotatory, which they borrowed from the work of the human arm; in later times designing engineers managed, with the aid of transmissions, to convert rotatory motion into translational as can be observed in modern planing machines (for instance, machines utilising the motion of the electric motor shaft). The technemes of

operators of metal-cutting lathes have thereby become much more complicated.

The development of the techneme as an element of work is of particular interest to physiologists and organisers of production. It is still unknown, however, how the more complex forms of work evolve from simple movements, for instance, how the movements of grasping, striking and pressing become the specific working movements of the fitter, turner, and finally, designer and organiser of production. This problem has not been sufficiently studied despite its great importance for the organisation of polytechnical training and improvement of the workers' skills.

Let us see how technemes develop historically. Every movement of a worker is undoubtedly a skill based on temporary nervous connections. In some instances it is even possible to determine the number of the basic motor reflexes of the hand—the elementary technemes employed in the given production process.

The physiological idea of technemes is closely related to the problem of tools, since the technical environment is the determining factor of development.

Revolutions in science, technology and culture, and, consequently, in human psychology can occur only in the complex interaction between man armed with work tools and nature which provides man with objects of work (Fig. 25). Such revolutions characterise definite historical periods and are the object of study of modern physiology of work and a source of further rationalisation of labour. While the qualitative and quantitative changes in the objects which come under man's technical influence are studied in the history of material culture, the history of man's influence on objects of work by means of a series of technemes or by more complex motor skills connected with greater complexity of tools, has not been adequately studied.

The number of elementary, fundamental work skills, i.e., technemes (motor conditioned reflexes of the higher order)

Fig. 25. Diagram showing development of work tools and gradual mastery of nature in the process of evolution of primitive technical skills and modern science.

1—rough-hewn stone; 2—axe; 3—knife; 4—lever; 5—needle; 6—spade; 7—fire; 8—pottery; 9—weaving; 10—tongs; 11—plough; 12—saw; 13—melting iron; 14—smithing; 15—grindstone; 16—printing textiles; 17—plane; 18—screw; 19—monkey wrench; 20—file; 21—joiner's bench; 22—tooth gearing; 23—milling cutter; 24—mainspring; 25—magnet; 26—printing press; 27—clock with pendulum; 28—support; 29—chemical research; 30—steam engine; 31—atmospheric electricity; 32—lathe; 33—rotary press; 34—electric motor; 35—electric bulb; 36—tractor; 37—aeroplane; 38—camera; 39—radio; 40—radar; 41—atomic energy; 42—biochemistry; 43—polymeric chemistry; 44—cyclotron; 45—cybernetics; 46—rocketry

and their connection with tools approximate to the number of phonemes in the second signal system.

The following is a list of the fundamental technemes whose combination produces a large variety of working movements connected with the increase in the number of work tools, the latter circumstance being characteristic of the present state of the productive forces of the human society. The list does not exhaust all the possible technemes, but contains some that are becoming more complex, namely: 1) striking, 2) pressure, 3) traction, 4) cutting, 5) wedging, 6) rubbing, 7) rotating, 8) weaving, 9) sawing, 10) loosening, 11) planing, 12) moulding, 13) grinding, 14) screwing, 15) piling, etc.

Every new techneme, i.e., every new way of handling a given tool or object of work, which requires a definite position of the hands and other parts of the body, is formed by superimposition and transfer, on the basis of formerly acquired skills corresponding to previously mastered work tools, with corrections for the new conditions of their application.

This order of development, which, along with social significance, has deep physiological and psychological roots, suggests the technique of *polytechnical training* to which Marx and Engels attached so much importance and which is implemented on a wide scale in the U.S.S.R., China and other socialist countries.

For a graphic illustration of the way in which technemes grow more complex we will consider cutting. The most elementary tool for cutting known since the stone age is the knife. A knife operated by an effort of the hand is a wedge. In it the centre of gravity and the fulcrum almost coincide. The techneme corresponding to the action of the knife is pressure. But if two knives are joined by means of a screw and the fulcrum is placed farther along the blades, the result is scissors, a lever of the second order. It is in this way that instruments appear with which it is easier to cut than with a knife. There are scissors for

cutting roofing iron. But in order to cut steel, to remove excess stock, another techneme is necessary—milling. The corresponding tool is, as it were, a combination of several wedges—the facets of the milling cutter that make repeated contacts with the metal and cut into it. Here the determining factor is the cutter revolving with the aid of a powerful motor; the whole mechanism of cutting is that of the wedge but at a higher, more perfect, stage.

With certain modifications the same applies to striking, traction, rotating and other elementary technemes which come into a complex relationship in the process of work.

Designing new work tools, which requires that the designers should clearly realise the purpose of the machine, know the shape and materials of the objects to be machined, the numerous elementary tools and materials of which the machine can be constructed, is one of the highest manifestations of the mind based on the work of the second signal system, clearly demonstrating the peculiarities of this system as compared with the first signal system and calling new types of technemes into existence.

Relationship Between First and Second Signal Systems in the Process of Creative Work

During the last period of his work Pavlov came close to the dialectical-materialist understanding of the higher mental phenomena, he determined their physiological substrate and formulated the basic laws of the connection between the first and second signal systems.

In speaking of the differences between the mind of man and the reason of animals Engels said that "the basic features of the method are the same and lead to the same results in man and animals, so long as both operate or make shift merely with these elementary methods.

"On the other hand, dialectical thought—precisely because it presupposes investigation of the nature of concepts

themselves—is only possible for man, and for him only at a comparatively high stage of development."*

As has been stated earlier, thinking is always closely associated with sensation and sensation gives rise to thinking. The activities of the higher and lower parts of the human brain are accordingly interdependent and unified. The activity of the higher parts of the brain is governed by the same rules and laws as that of the lower parts and of the sense organs: in each of these instances we deal with reflection of the objects and phenomena of the surrounding world, in the former instance—indirect and in the latter—direct.

Man cannot all at once grasp and embrace all of reality with his sense organs, i.e., his first signal system. The results of abstract thinking associated with the higher centres of the second signal system develop in a definite order and often become more concrete than those of thinking in graphic images.

As has already been noted, the two opposite forms of the single nervous process—excitation and inhibition—come into contact in the human brain, become delimited, exclude and at the same time evoke one another. The higher nervous centres of animals are the arena of constant struggle between these processes.

In man the conflict, the interaction of excitation and inhibition in his second signal system in general is especially acute and complex. This conflict of the opposites at the same time serves as the basis for the appearance of new properties of higher nervous activity, sometimes called "the throes of creation". Inventors and production rationalisers are familiar with this state.

In studying the interrelation between the first and second signal systems Pavlov also investigated the problems of creative work. He drew the following scheme which is still valid today.

* F. Engels, *Dialectics of Nature*, Moscow 1954, p. 296.

"Life clearly reveals two groups of human beings: artists and thinkers. The first group—artists—perceives reality as a single whole, that is, all of living reality without breaking it up or dismembering it. The other group —the thinkers—on the contrary, dismember it and thereby, as it were, kill it and make of it a kind of temporary skeleton; only afterwards do they gradually seem to assemble its parts anew."*

As an observant researcher Pavlov found that "... by virtue of the long-established different modes of life, human beings in the mass have been divided into artistic, thinking and intermediate types. The last-named combines the work of both systems in requisite degree."**

Some of Pavlov's students were puzzled by this division into the "artistic" and "thinking" types, and believed that the "lower" first signal system predominated in artists. This is wrong, because Pavlov introduced these terms for his clinical work to characterise the peculiarities of the patients' perception, which were determined not by their occupations but by the nervous types to which they belonged. There is, therefore, no ground for reproaching the great physiologist with underestimating the artists' abilities for abstract thinking.

An artist must have a fine sense of colour and be able to reproduce aerial perspective by gradations of colour; he may paint or draw, belong to one school or another, be a realist or symbolist, have his own convictions and have his own interests in the history of his art, all this meaning that he is master of all the resources of his first and second systems, which is what we actually see in life.

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* I. P. Pavlov, *Psychopathology and Psychiatry*, "Essay on the Physiological Concept of the Symptomatology of Hysteria", Moscow p. 542.

** I. P. Pavlov, *Experimental Pathology of the Higher Nervous Activity*, "Types of Higher Nervous Activity. Their Relationship to Neuroses and Psychoses and the Physiological Mechanism of Neurotic and Psychotic Symptoms", Moscow, p. 490.

Can there be a harmonious combination of the two systems?

In his "Realm of Darkness" the Russian author and literary critic Nikolai Dobrolyubov, whose authority in literature Pavlov very highly esteemed, said the following: "As a matter of fact the thinking powers and creative ability are both inherent in and equally necessary to the philosopher and the poet. The greatness of a philosophical mind and of a poetic genius consists in the ability at first glance to distinguish between an object's important and chance properties, and then to form a correct picture of them in one's mind and master them.... But the difference between a thinker and an artist is that the latter's perceptions are much more vivid and powerful.

"Both base their world outlook on facts that have reached their consciousness. But a man with more vivid perceptions, the so-called 'artistic nature', is more impressed by the first fact of a certain type encountered by him in surrounding reality."

For a scientist, however, the first facts are not enough, he generalises the phenomena of reality and tries to penetrate into their essence.

Nor can an artist, however, be content solely with the impressions provided by the first signal system. Pavlov's words, "Do your best to get beneath the skin of the facts. Search persistently for the laws governing them", can equally be applied to scientists and artists.

It should be noted that the painter, the writer, the poet use emotional means to embody their artistic conception, unconsciously counting on the force of the orienting reflex. Reproduction by a painter of his former, even most effective and characteristic images, in another picture greatly weakens the spectators' orienting reflex, that is, dulls their interest and attention. The epithets and metaphors attracting the reader's attention by their originality and poetic force cannot be repeated without loss of their effectiveness.

Thus we see that the creative effort of artists as well as scientists admits of physiological analysis without in any way detracting from the dignity of science and art in our opinion.

To the end of his days Pavlov waged a struggle for the purity of materialist conceptions in the science of the brain. Soviet physiology developing Pavlov's ideas of the significance of the second signal system emphasises the role of work in its evolution.

Work is a means of remaking the surrounding nature and not only one of man's adaptation to it. It is important for the remaking of the environment and of our own psychology. All this fully agrees with the main theses of the founders of Marxism-Leninism: "Natural science, like philosophy, has hitherto entirely neglected the influence of men's activity on their thought; both know only nature on the one hand and thought on the other. But it is precisely *the alteration of nature by men*, not solely nature as such, which is the most essential and immediate basis of human thought, and it is in the measure that man has learned to change nature that his intelligence has increased."*

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* F. Engels, *Dialectics of Nature*, Moscow 1954, p. 306.

CHAPTER SEVEN

SEVERAL PROBLEMS OF PHYSIOLOGY AND HYGIENE OF PHYSICAL WORK

Essence of Working Skills and Habits

Textbooks of methods of vocational training often distinguish between *habits* and *skills* as applied to workers, students of vocational schools, etc. The idea is that habits denote automatic acts, conditioned reflexes and inhibitions and therefore belong to the sphere of neurophysiology, while skills rather imply the solution of creative problems, independent performance of certain operations, rather than mere repetition of past experience, i.e., belong to labour psychology (mental activity) and characterise an individual's attitude to his work.

This differentiation between habits, on the one hand, and skills, or creative effort of the social man, and especially the systems of knowledge, the foundations of sciences, on the other, seems rather artificial from the standpoint of Pavlov's conception of the organism as a whole and is not borne out by practice. Actually no physical habit, even one of very long standing, ever becomes wholly mechanical (automatic) or develops into an unconditioned reflex, but is likely to become disinhibited, deautomated, which often leads to errors in work, mistakes in writing, etc. On the other hand, every skill which is always acquired in the process of work, and the mastery of a vocation, always include a long series of conditioned

reflexes of the second signal system and are, consequently, connected with the activity of the higher parts of the brain governed by the laws of physiology.

The authors who thus distinguish between habits and skills (knowledges) point out that the former are practically impossible without the latter and that the two together make up the valuable property known as efficiency. Without a conscious attitude to one's work habits are of no value, just as knowledge by itself is of little avail to the person who cannot handle elementary work tools, the requisite machinery, etc.

From our point of view substantiated by all that has been said above, the main difference between working habits and skills (knowledges) is that the former belong mainly (but not exclusively) to the reflexes of the first signal system, i.e., the direct perceptions of the brain, its motor analyser playing a particularly important part, while the latter, providing good orientation under new and uncustomary conditions, belong to the reflexes of the second signal system which requires the participation of thinking in abstract concepts that develops later than thinking in concrete images. A skill is not a mere sum of many habits.

Whereas the second signal system is the result of the activity of the same nervous tissue as the first, the same laws of higher nervous activity govern skills (knowledges). At the same time there are naturally differences and even contradictions between the two systems. This finds expression in the fact that some students (depending on the type of their nervous system) easily acquire knowledge from books or lectures and are even able to give advice to others, but cannot do anything with their own hands, their work often being of inferior quality. This means that in them the second signal system predominates. Others, on the contrary, very enthusiastically acquire working habits, but are unable sufficiently to generalise their experience and even less so to pass it on to others orally,

in writing or blueprints. In their working processes it is the first signal system that predominates. But there is a numerous group of innovators in production, rationalisers of working processes in whom both signal systems function equally well.

It is precisely such a synthesis that should be developed in workers and pupils both at schools and at work.

Timing Working Operations

Timing, i.e., precise determination of the period of time a given operation requires, is the most popular method of research in labour physiology in industry and the basis for rationalising the process of acquiring useful new skills.

The timing is done by means of a stop watch, chronoscope or a timepiece which records thousandths of a second (Fig. 26), as well as by filming different operations by the rapid method with subsequent slow projection, and analysis of the individual elements of the movement, as is done in cases of athletic events at stadiums. Of late electronic recording with photocells, like sound recording in the talking pictures, has been used; in this method a definite combination of lighted and shaded squares corresponds to each movement. This recording of movements in time and space is done by so-called binary coding, used in modern cybernetics. It is also used in recording the movements of a worker at his bench. The cycle of operations performed by one worker to produce one article is taken as a unit and in this way the worker's efficiency

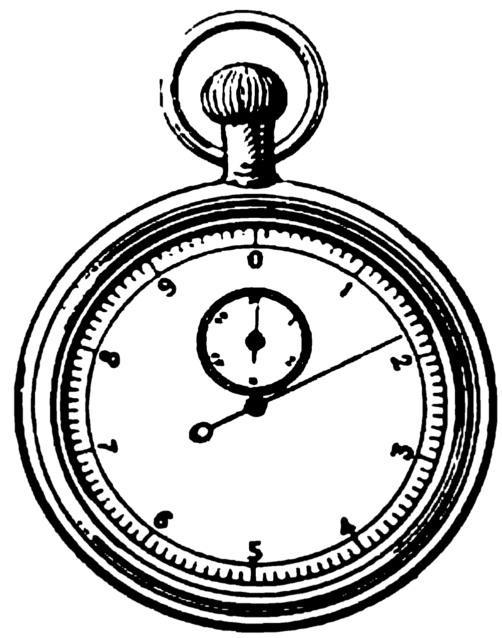


Fig. 26. Stop watch showing thousandths of a second for timing working operations

is measured under conditions obtaining at the given enterprise with due regard for his length of service and qualifications.

In his book dealing with working on lathes P. Bykov, highly-skilled turner and innovator, suggests the division of the working hours in the metal-working industry into *working time* proper and *rest time*, the latter including the lunch interval, changing the clothing, washing up and, in certain cases, the setting-up exercises which are recognised as a good method of controlling fatigue.

The working time is subdivided into: a) preparatory and round-off time, b) productive time and c) auxiliary time (putting in order one's working place, etc.).

The preparatory and round-off time is spent on work done in preparation for machining a batch of parts, mostly of the same type, receiving an assignment from the foreman, setting up the machine and handing in the finished product. All this takes about 28 per cent of the working time.

The productive time, which is spent on the production of each piece, is further divided into *machining* time and *handling* time. The machining time is spent on working the metal and takes up nearly 30 per cent of the working time. The handling time is spent on fixing, adjusting and removing the parts, manipulating the support which holds the tool, checking the allowance with a measuring instrument, altogether 34 per cent of the time (the worker operating a single lathe).

Lastly, the timing includes the time spent on servicing one's working place—preparing it for the next shift, putting everything in order, removing the shavings, etc., which takes up 3 per cent of the time.

The struggle for raising labour productivity is aimed mainly at increasing the machining time, which means cutting the time for preparatory, finishing and auxiliary operations, which consume nearly 70 per cent of the working day, and at a better utilisation of the machining time

through boosting the revolutions of the lathe, introduction of various appliances which reduce the machining time per unit of production. Improved technology also plays a big part and consists of curtailing the operations, reducing the allowances, improving the tools (quality and shape of the cutters), and lastly, keeping the tools and parts to be machined in order.

According to Bykov, all these methods, in mass serial production, save up to 57 per cent of the time and double labour productivity.

What has been said about the saving of time on auxiliary operations should not lead one to think that these operations are unimportant. In preparing for the work process, in setting up any kind of production, as well as in everyday life, particular attention must be devoted to such operations as putting in order one's working place whatever it may be (a templet moulder's table, a loom, a writing desk or a sewing-machine). In the course of time, when the preparation and putting the working place in order have become a habit, a behaviour pattern, one will be able to reduce the time for these operations, concentrating a maximum of one's attention on the chief productive operations which yield direct and tangible results. In addition, the thing to remember is that the auxiliary time can and must be reduced by improving the production processes, namely, fixing the parts by means of special mechanisms rather than manually, automatic checking of the cutting, etc.

Cleanliness of the working premises is of particular importance for it is a potent factor in raising labour productivity and it at the same time bears on the functioning of the nervous system. It is well known that cleanliness of the working place, the working clothes, the floor, etc., minimises the chances of infection.

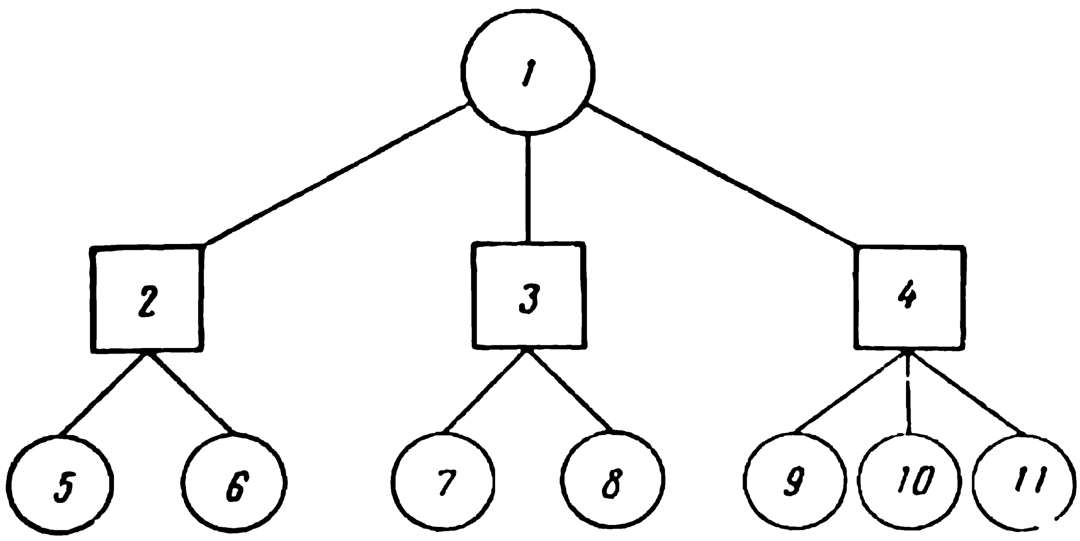
Here we are not considering the role of cleanliness in preventing occupational diseases caused by harmful dust, vapours of certain chemicals, radioactive radiation, etc.

Even if all harmful factors were eliminated by safety measures, cleanliness would still be essential, since it is a neuro-psychic factor which stimulates work no less than precise calculation of operations, well thought-out production plans or rationalisation measures. That is why putting in order one's place of work, the whole shop and the machine should be regarded as one of the obligatory operations.

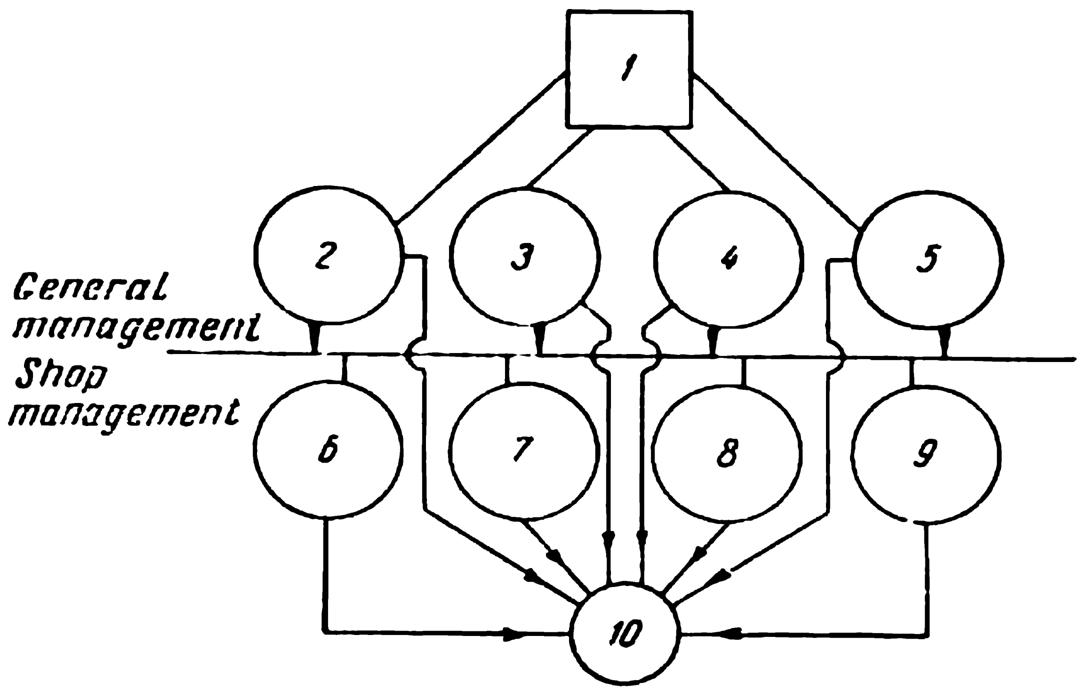
F. W. Taylor's "Scientific Management" System and Its Criticism

An important development in the physiology of work that played a big part in determining the role of the "human factor" in production took place during the last quarter of last century. On the initiative of engineer Taylor the metal-working enterprises, first in the U.S.A. and then in Europe, adopted a system of dividing work into very small elements, each worker doing only one element. This resulted in a considerable increase in the output, since every worker by constantly repeating the same movement performed his operation very quickly. The performance of the best workers, for whom optimum conditions were set up, was timed by means of a stop watch to the hundredth fraction of a second, following which all workers were made to work at the same speed, often without any improvement in the working conditions. All this made it possible to double and even treble labour productivity.

The reform in the management of shops and entire enterprises initiated by Taylor made the supervision and management of the work of a shop or an enterprise the business not of one foreman, as before, but of several foremen or superintendents. Each had his own aspect of work to supervise; one taught the worker and saw to it that he received his instruction card and drawings, another supervised his setting up the parts in the machine and economy of movements, a third one (the speed boss) was



a



b

Fig. 27. Two systems of shop management. *a*—old line supervision: each worker (2-11) is subordinate to one foreman; *b*—Taylor's Functional Foremanship: each worker (10) is subordinate to eight foremen

a specialist in cutting tools, speeds and everything concerning it, a fourth one (the repair boss) was responsible for repairs, etc. The two diagrams shown in Fig. 27*a* and *b* offer an idea of this form of work organisation.

It is easy to see that the Taylor system, although pretending to be scientific, applies the same, purely super-

ficial, methods of measuring the performance of both men and machines, drawing no distinction between human beings and mechanisms and disregarding the fact that workers tire. It is quite natural that the output should decrease when the worker is tired, for instance, at the end of the working day. It goes without saying that Taylor ignored the personalities of workers, their inventiveness, etc.

Some of his suggestions, such as preventive repair of the tools, well-functioning shop transport, improved working conditions, improved tools, were definitely progressive. However, all these improvements were not aimed at securing a better life for the workers but at increased exploitation, of which Taylor himself spoke with cynical frankness. To justify the necessity of systematically raising the quotas and lowering the rates he said in his *Principles of Scientific Management*: "When they (workers—*Y. F.*) receive much more than a 60 per cent increase in wages, many of them will work irregularly and tend to become more or less shiftless, extravagant, and dissipated."

Emerging in the 1880s, the Taylor system became fairly widespread during the subsequent decades, finding realisation in various types of conveyer systems of organisation of production. All of them are based on subdividing an operation into a series of small separate elements performed by individual workers, unified by the sequence in carrying out a common assignment and one working rhythm.

A conveyer system makes it possible to dispense with skilled workers because each element of the operation can be performed by any worker, after a short term of training, with high labour productivity as a result. Obeying the unified pace of the conveyer and performing the same simple operation day in and day out, a worker produces much more than he would without the conveyer. But from the physiological viewpoint this system is regressive.

The system of work organisation advocated by Taylor and his followers, in which a worker is no more than an appendage to a machine, Lenin called "a system of scientific sweating". Although the conveyer system increases labour productivity, is usually accompanied by a certain rise in wages and, by reducing the work of each worker to a single operation, seems to facilitate the learning of a trade and the work itself, the class-conscious workers in capitalist countries are waging a just struggle against it. To perform one set of movements for a long time is an unendurable strain, and not so much physical as neuropsychic.

When a person does complex work involving different movements, his cerebral centres are alternately excited and inhibited, which enables them to restore their efficiency and makes them less susceptible to fatigue. Under the conveyer system the worker is restrained by the rhythm of production and performs monotonous work repeating the same movements for many hours on end. This monotony leads to overstrain of the corresponding cerebral centres and impairs the worker's health.

* * *

The problem of raising labour productivity in the Soviet Union is solved mainly by automating production and reducing the share of physical work.

Only such organisation of production in which harmful, hard and exhaustive physical operations are performed by machinery with workers supervising them can combine increased labour productivity with protecting and safeguarding the workers' health.

Today the U.S.S.R. has many fully automated shops and factories and their number will grow with each passing year. The chemical, motor, ball-bearing and radio works are being automated at a particularly rapid pace.

Several shops of the Lebedev Synthetic Rubber Plant in Yefremov, for instance the divinyl production and purification shop, which is one of the plant's most important shops, are fully mechanised. This shop is housed in an immense building several storeys high and has some 150 complex installations some of which are 5 and 6 storeys high. No workers are to be seen on the premises, the installations being operated by one engineer, the shift superintendent who, sitting at the control panel and watching the readings of the instruments connected with the installations, merely pushes the necessary buttons. There are many such shops at this plant. The work of the furnaces in the shop of contact decomposition of alcohol where extremely complex processes are operating is controlled by a quick-action electronic machine. The machine detects deviations in the functioning of the units and signalises to the operator the place and time of the deviation.

Automation and mechanisation of production are also being effected in the capitalist countries, although they pursue different aims, namely, still greater exploitation of the remaining workers and their further subjection to the rhythm and speed of the machinery. It will be noted that any mechanisation and automation of production processes in capitalist countries leads to mass layoffs which further aggravate the already acute unemployment. In the Soviet Union mechanisation and automation lead to a shorter working day, as envisaged by the Seven-Year Plan.

Doing the bidding of monopolists, some U.S. physiologists praise the positive aspects of the conveyer system, but consciously avoid the problem of the higher forms of activity of the brain connected with work and of the harmful consequences of the "scientific system of sweating" for the working people, at the same time failing to take notice of the outstanding creative abilities of worker inventors.

Peculiarities of Work Under Conditions of Modern Serial Production

What is modern serial production and how does it differ from the organisation of production in the past? For example, the work of a big machine shop (Fig. 28) is characterised primarily by a rapid *tempo*. The construction of modern lathes and the higher quality of the cutting tools make possible a hundredfold and even greater increase in the cutting speed. In addition, most of the operations are mechanised, there is a tendency to standardise production according to type, size and grade, and, lastly, the enterprises are specialised and coordinated.

These progressive features of mass production are intimately connected with a check-up on the *productivty* of each worker, planning, quotas, differential rate piece work, automation of the *controls*, etc., all of which factors are in turn related to the physiology of work and the psychology of the workers.

In the U.S.S.R. and the People's Democracies, where nation-wide planning is practised, the specialisation of enterprises provides for linking the different factories in chains, each link of a chain being highly specialised and, consequently, most productive.

Another very important factor in a large country is correct geographical distribution of the industrial enterprises close to the sources of raw materials and areas of consumption. If this factor is neglected, vast transport expenditures may bring to naught all the economy from manpower and material resources effected through the aforementioned methods of industrial rationalisation.

Many factors must apparently be taken into account before considering the question of physiology of work and utilising this physiology for raising labour productivity within one factory, let alone all of the national economy.

Thus the questions of physiology and organisation of work and consideration of the human factor in production

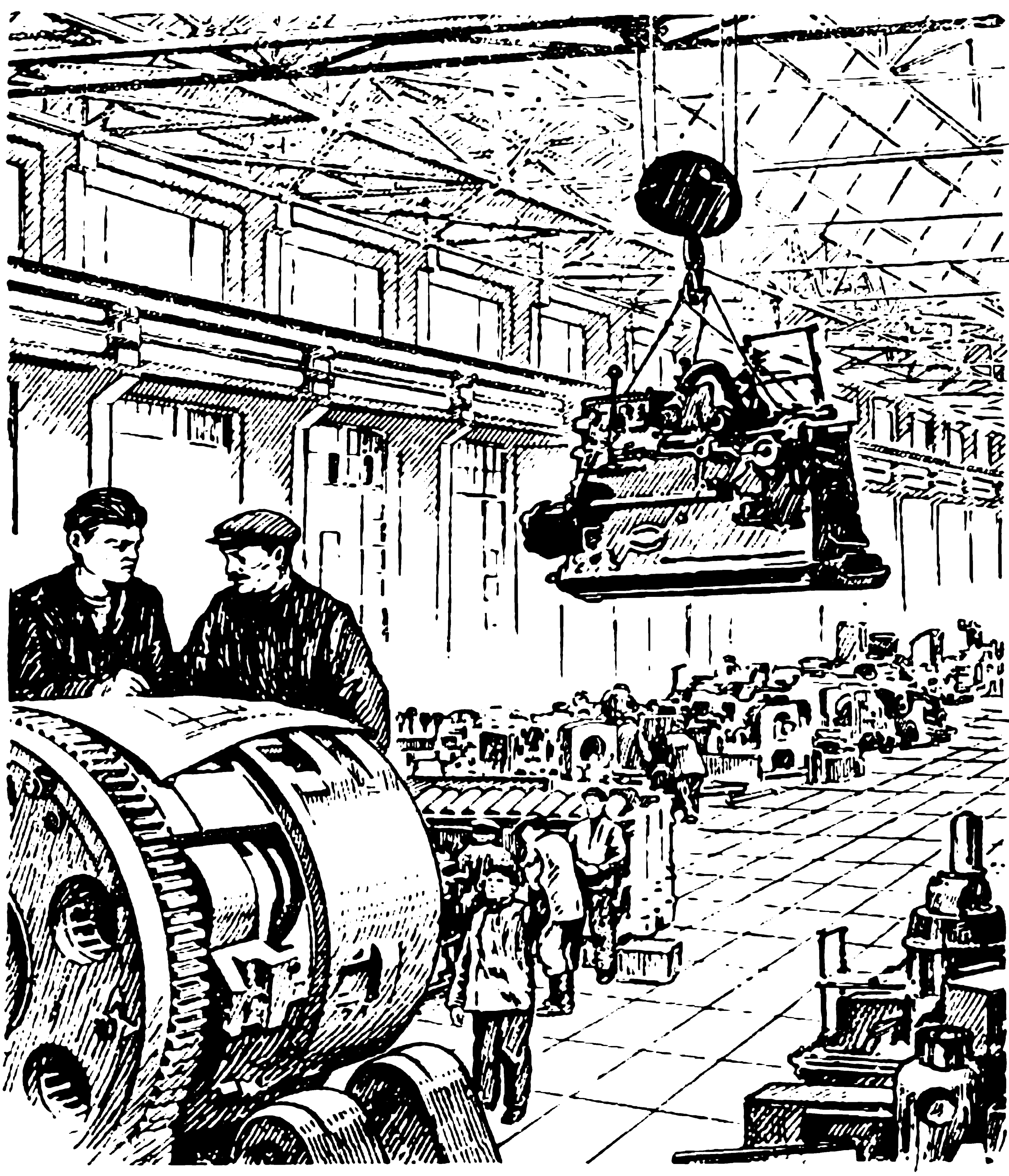


Fig. 28. General view of modern machine shop

rise before us against the background of a vast complex of economic and technical problems which grow still more complex as the organisation of production develops and improves, and new materials, new forms of energy, etc., are discovered.

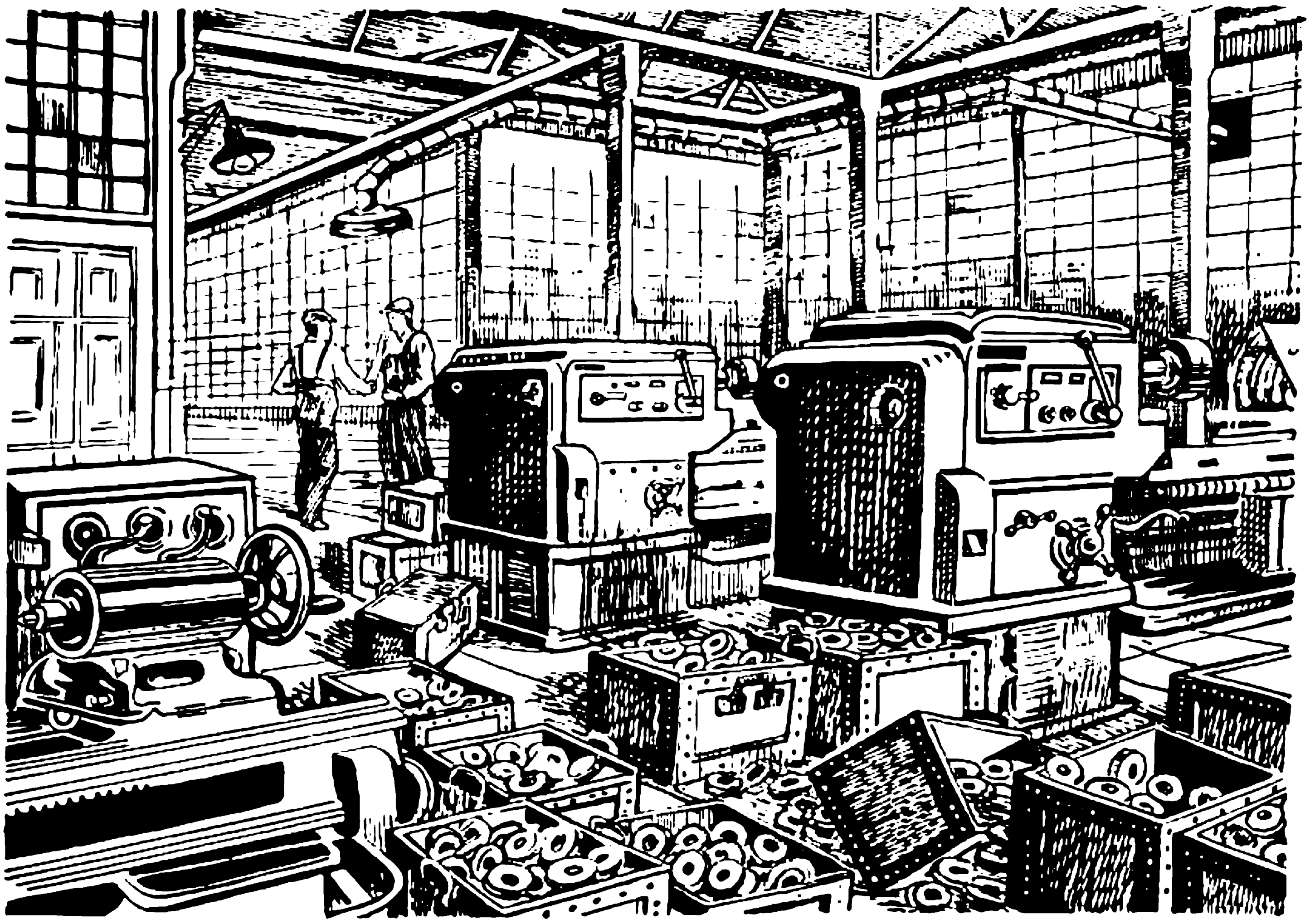


Fig. 29a. Poor organisation of work in a shop

Under modern conditions technical progress is determined not only by improvement of the technology of production, of the technical means, but also by a better organisation of the labour process. It includes, in the first place, technical control of the products and improved management of the enterprise as a whole, i.e., organisation of the dispatcher service, etc. Other important problems are the transport facilities within an enterprise and within individual shops with extensive opportunities for rationalisation, and the location of store-rooms for the materials, parts and tools moving from one shop to another and from one operation to another. Any oversight in the complex system of organisation and management of enterprises leads to derangement of production, a fall in labour productivity, whose rise is the main requirement of mod-

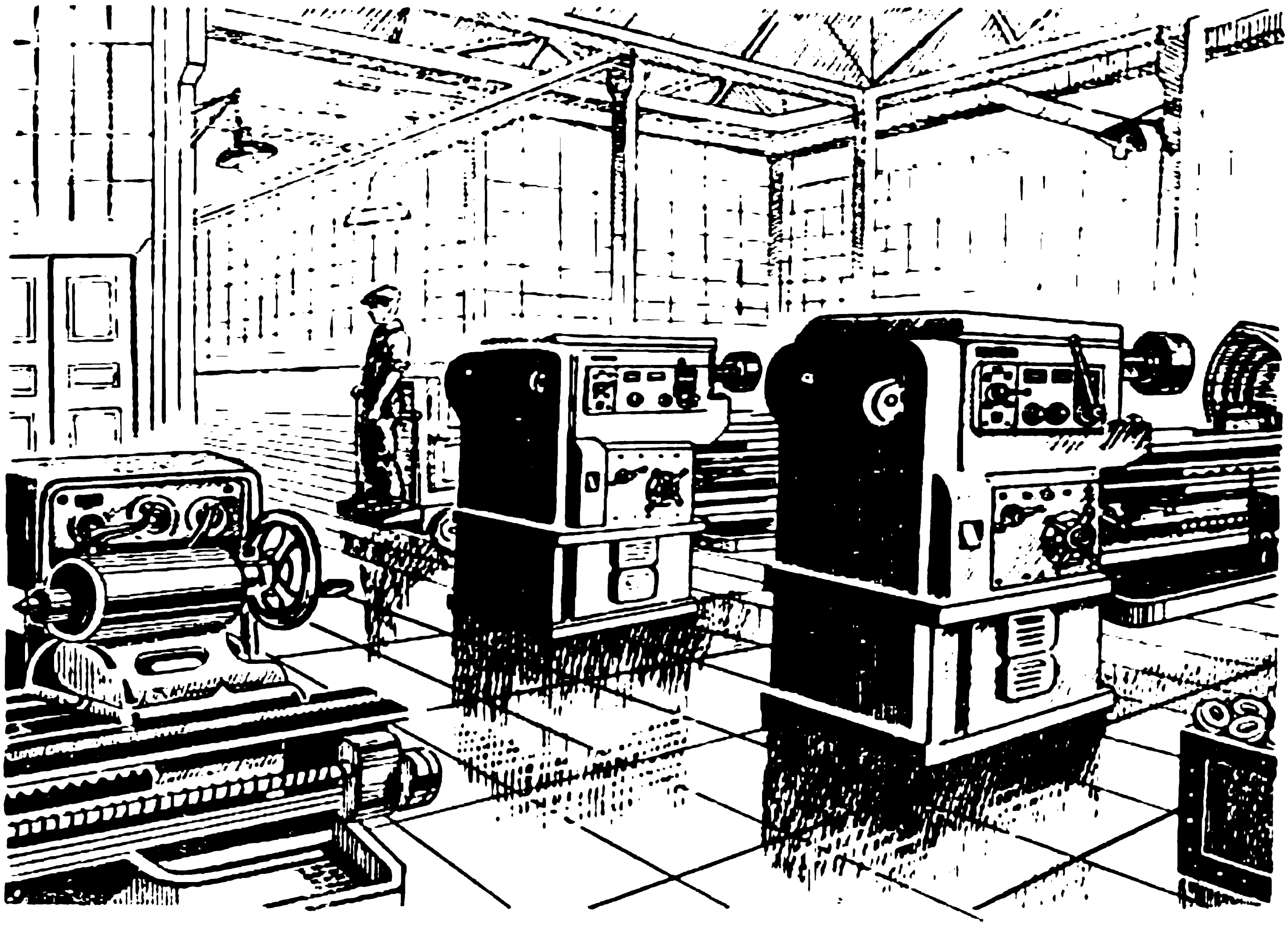


Fig. 29b. Same shop after reorganisation

ern economy and the basic factor of technical progress (Figs. 29*a* and 29*b*).

Designing new and more efficient machines, machine tools, and other production installations plays no small part in the technical progress of modern large-scale enterprises. They are designed on the basis of the experience of a given factory by its own engineers and are often built at the very same factory. This in effect imparts to many enterprises the functions of research centres.

Current and capital repairs of a large enterprise provide for re-equipment of the machinery and various installations to meet the new requirements for raising labour productivity, namely, higher speeds, automation of auxiliary operations, etc.

Automation of individual machines, production lines, shops and factories with the aid of cybernetics, electro-

nics and telemechanics is a decisive factor in raising labour productivity, and at the same time raises new questions of organisation and physiology of work.

In working out technical solutions for the problem of automation, engineers very largely draw on the achievements of physics, chemistry, biology and mathematics. This makes it possible radically to improve the conditions of human labour, shorten working hours, etc.

A characteristic feature of large modern enterprises is sharp demarcation between productive work and all *auxiliary* operations, such as removal of waste material, which is assigned to auxiliary workers. The same applies to underground work (for example, coal mining) where cutters are freed from all secondary duties, which reduces the idle time of boring machinery and leads to rhythmic work.

Physiologists must not disregard the organisation of the auxiliary operations. These operations are unthinkable without mechanisation and automation of production processes in industry and agriculture.

The vicious Taylor system which ruthlessly destroys the working people in capitalist countries, body and soul, can find no application in Soviet industry. Socialist agriculture finds no use for such methods of land tilling, based on manual labour, as still doom small peasants and farm labourers to work from sunup to sundown in some foreign, particularly colonial countries. In the U.S.S.R. unemployment has been abolished and a six- and seven-hour working day has been introduced. Under these conditions the labour productivity of all workers can be raised and production expanded to the extent at which it will be able to satisfy the increased requirements of the population for housing, foodstuffs, consumer goods, schools, clubs, theatres, hospitals, etc., only by further improvement of the production methods and by raising the general industrial efficiency. Observance of the rules of hygiene by the workers themselves is an important factor.

At the same time technical progress must envisage a

considerable bettering of the working conditions. All hard, dirty and harmful operations must be automated and mechanised in the first place. Rationalisation of production must lead not only to raising the productivity of labour but also to sanitation and improvement of all working conditions. One of the prerequisites for achieving this is thorough knowledge of the physiology of physical and mental work in all of its varied aspects.

Static work has been established to be the most fatiguing form of physical labour. The brain grows catastrophically more tired with each passing minute. To be sure, in exceptional cases the organism can endure great strain in doing static work in a state of considerable emotional excitement, for instance, a mother holding long her sick child in her arms, a fireman holding a heavy fire hose, a circus artist during a performance, etc. At any rate, static muscular effort is always less beneficial to an organism than is dynamic work of a cyclic and rhythmic nature, even if it is harder, for example, wielding a sledge-hammer. In the latter instance the movements of the muscles alternate as does the work of the centres of muscular regulation. In rationalising work in a shop it is, therefore, primarily necessary to reduce static work to the minimum, particularly, to substitute a sitting posture for standing (in physical work).

Another type of nervous overstrain in physical work is excessive division of a working operation into fractional elements, which, even if facilitating work, deprives it, as has been pointed out earlier, of all meaning. Excessive differentiation of muscular movements involves extremely fine, mosaic, distribution of excitation and inhibition foci in the cerebral cortex (the motor analyser), which may cause a nervous break-down with its consequences injurious to the worker's health.

Such division of labour operations with numerous repetitions of one element per time unit is sometimes ob-

served in the conveyer system which by itself is a progressive form of the production process.

In the Soviet system of organisation of conveyer work fatigue is controlled by periodical changes in the operations performed by each worker. Another method of eliminating monotony is changing the speed (rhythm) of movement by increasing it in the beginning of the working day, regular intermissions at the end of every hour and gradually slowing down towards the end of the day.

Setting-up exercises before work, a restful lunch period and corrective exercise sessions during the day, all tend to prevent fatigue. All these simple and easily implemented measures prevent the harmful effect of fatigue on the nervous system and the organism as a whole.

A substantial achievement in rationalising line production with due regard for the physiological factors is an *alternating* acceleration and deceleration of the conveyer, which, according to S. A. Kosilov, exerts a beneficial influence on both the nervous system of the workers and the productivity of the conveyer. At the enterprises where the physiological factors were taken into consideration in rationalising the work (an electric bulb plant, the Krasny Treugolnik Rubber Plant, watch and clock factories and the Kalibr Works) a considerable rise in labour productivity was observed (data of the Labour Hygiene Institute of the U.S.S.R. Academy of Medical Sciences).

In 1956 physiologists were often seen in Shop 4 of the Krasny Treugolnik Rubber Plant. They wanted to liven up the very monotonous process of conveyer production of rubber goloshes, because the workers laboured under great nervous strain since the work required close attention.

M. I. Vinogradov, Professor of Leningrad University, and V. S. Vorobyova, Master of Science in Biology, conducted a series of laborious studies in the shops.

On Vorobyova's suggestion a new working regimen was introduced into the morning and evening shifts (the time

of the lunch period was changed and several five-minute recesses were added). After two months' work according to the new scheme a check-up was made.

The aforesaid measures essentially changed the efficiency curve, relieved the nervous strain of the workers and aroused their labour enthusiasm. The efficiency curve in both complex and simple operations acquired stability.

It follows that the undesirable effect of monotonous work can be eliminated by means of scientific organisation of production. But the problem also has other aspects.

One of the worst consequences of the conveyer system at large-scale capitalist enterprises is despecialisation of the workers. Owing to the simple working movements required for work on the conveyer the skilled workers are replaced by unskilled workers. This despecialisation justified J. Ruskin's statement as far back as fifty years ago that the division of work operations on the conveyer into minute elements was equivalent to breaking up the human brain into small fragments.

The Soviet Union is carrying into effect a *positive* "despecialisation" which provides for mastering *several vocations* by each worker. This is being implemented on an increasingly larger scale with the result that every worker wants to learn the fundamentals of the production process as a whole, including its theory, technology and economy. This type of "despecialisation" is expedient and physiologically justified, for it develops in equal measure all aspects of mental activity, trains all the higher brain centres, develops the second signal system and lends a creative character to the activity of the brain.

This trend is connected with *polytechnical* education as a method of training new workers. It also covers the physical education and athletic training of the workers.

There are other physiologically important questions concerning rationalisation of work at industrial and agricultural enterprises, but they cannot, as a matter of regret, be discussed here for lack of space.

Mechanisation of Production and Rationalisation of Work

As has already been said, the best and simplest form of rational organisation of work, providing for freeing the worker's muscular system, is overall mechanisation of the production process. Owing to increased speeds and the higher precision of work, however, mechanisation, while freeing the muscular system, intensifies higher nervous activity, requires better skilled workers, imposes a heavier strain on their second signal system and puts many new problems before hygienists and organisers of production.

Mechanisation of physical labour has proved particularly important in agriculture where the substitution of the tractor or harvester combine for the primitive wooden or horse-drawn iron plough has wrought a veritable revolution in the life of the community. As long as workers of all enterprises are trained for particular vocations we may speak of occupational physiology and hygiene of fitters, turners, forge press operators, chemical industry workers, wood-cutters in the timber industry, etc.

Each of these vocations has its own characteristic behaviour patterns also found only in a few related occupations and capable of being rationalised in various ways with due regard for neuropsychic (and not merely physical, muscular) factor.

What general rules for rationalisation of mass occupations have been established as a result of the studies in physiology of work?

First, a thorough *preparation* of the working place for the forthcoming operations; this includes the preparation of the necessary tools and their convenient lay-out (Fig. 30), according to the rule "put on your right all that you take with your right hand and on your left all that is meant for the left hand", checking on the technical documents, instructions and instruction card, which must always be before the worker's eyes. Last but not least, provisions for transporting the parts to be worked.

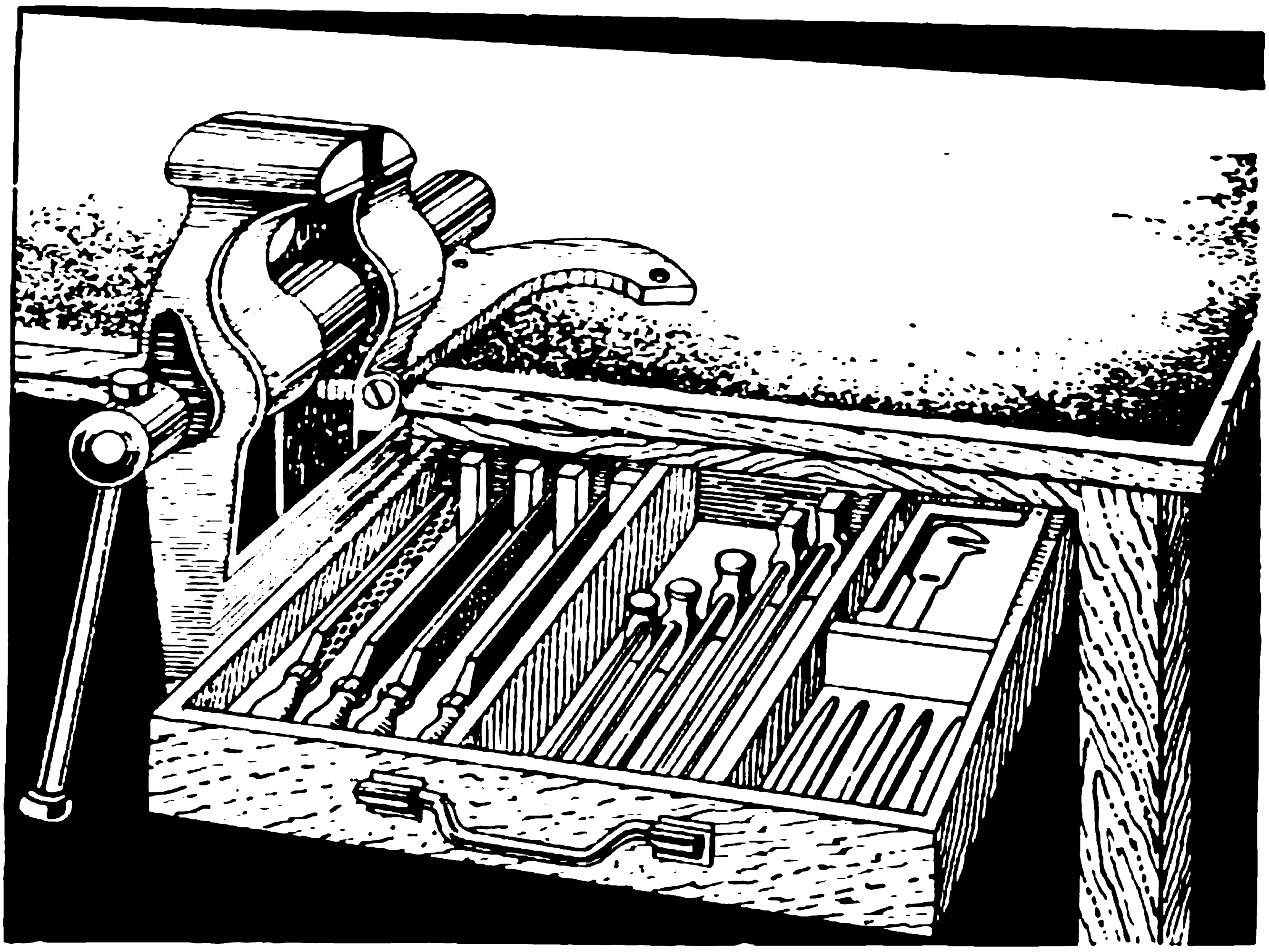


Fig. 30. Rational lay-out of fitter's tools

The dynamic pattern in the brain of the worker must not be disturbed every time he changes from one cycle of work to another and no useless operations, such as looking for mislaid tools, waiting for parts, etc., must be allowed to inhibit the established psychological attitude, for they all interfere with the correct functioning of the brain.

For the same physiological reason (the danger of disturbing the pattern) it is advisable to begin with a series of *similar operations* (felling trees, clearing them of the branches, sawing and rafting them, in case of a timber-cutter), because excessively quick alternation of the working patterns lowers labour productivity. But, of course, everything depends on the concrete conditions in each individual case.

Maximum utilisation of natural forces, for example, gravity, is an important principle of rationalisation. This requires placement of all parts to be machined on a level with the worker's height so that the latter may not have to lift or reach for them and thus waste some of his efforts. This is connected with the problem of rationalising transport facilities (shop transport in particular), i.e., well-timed transfer of the parts from one machine to another, which, in the long run, leads to dismemberment of the production operations and to conveyerisation of various degrees of complexity (movement in batches, continuous flow, etc.).

As a minimum, organisation of the working places of metal-workers, textile-workers, wood-workers and workers of other analogous occupations requires the smaller parts to be brought to the operator in sufficiently high trucks equipped with shelves and prevention of cluttering up the working place with finished or semi-processed goods since they hamper the worker's movements and divert his attention, whereas the worker's attention is one of the most important factors.

Our short list of the means of physiological rationalisation in the shop may be concluded with mentioning the necessity of scientifically established *speed* and *rhythm* for each type of work and each operation which make up individual and collective labour.

A sharp distinction should be drawn between the speed of work and its rhythm. The speed at which an operation is performed may be high or low, more or less strenuous. A five per cent increase in the speed of work all through a given process may not be noticed by the workers at least in the beginning. But if the rhythm, regularity of movement or of the working process is changed but a few per cent, it will not only be immediately noticed by the workers, but will also affect their physical condition and productivity of labour.

It is clear that every worker ought to know the possible rhythms of all operations and do his best to improve them. But having selected the optimum rhythm he should keep it up. A steady rhythm of work can in certain measure compensate for insufficient speed.

From the foregoing it follows that modern industrial enterprises offer a vast field for applying scientific methods of organising physical labour and that this field is constantly expanding. There are equally extensive possibilities for introducing hygienic measures in shops and on farms, although much less attention is being devoted to them than to rationalisation of production.

Despite the mechanisation effected in a number of industries and the transport, the role of the worker, i.e., his participation in production, is still very important. His neuropsychic activity must be an object of the most intimate concern on the part of organisers of production, inventors of new machinery, etc.

In general, modern automated industry calls for very highly skilled workers, who must meet its new and more exacting requirements. It presupposes combining work with training, which is being achieved in the U.S.S.R through a wide network of evening and correspondence schools.

CHAPTER EIGHT

CAN MENTAL WORK BE SCIENTIFICALLY ORGANISED?

Health and Creative Efficiency in Mental Work

In discussing the problem of rationalising mental work by modern physiological means, some scientists ask: "How can one tell that a mental worker who rigorously observes a prescribed regimen of work and relaxation is the most talented and efficient?"

This direct question is certainly not easy to answer. Statistics operating with large figures admits some exceptions to rules, but, for all that, the fundamental premise of physiology, namely, the necessity of an objective approach rather than subjective "judgement" and order instead of chaos, remains valid. This also applies to scientific organisation of mental work where order triumphs over lack of system and arbitrariness. The advantages of healthy cerebral activity are obvious, and it is high time to put a stop to an irresponsible attitude to physical and mental health.

To those who say, "Prove that my organisation of work is worse than yours," we must point out the results of the research in physical labour and the attainments of industrial hygiene at numerous modern enterprises where rationalisation has become part and parcel of daily life. Those who are accustomed to do as they like and to work in a "what-was-good-for-my-father-is-good-enough-for-me"

way, that is, as individual scientists worked hundreds of years ago, should be made to realise what would happen if every shop and every factory organised their work in their own way, if every modern physician were to invent his own drugs and prepare them himself as did Dr. Faustus in the Middle Ages.

In the U.S.S.R. and in the People's Democracies the difference between mental and physical work is being gradually eliminated, physical workers acquiring more and more knowledge and approaching intellectuals in their development and education. Increasingly more workers are becoming rationalisers and inventors. They work not only in the shop or the designing office, but also at home. Under these conditions the problems of the physiology and protection of mental work, as well as of a conscious attitude to it, acquire particular importance. But little attention is as yet being devoted to the hygiene and organisation of mental work, especially in the case of young people. All this makes the principles of rationalisation of mental work problem number one. This problem also deals with maintaining the efficiency of a large group of people who possess a vast store of experience, with keeping them in good health and improving their performance.

It sometimes happens that a very well conceived and well planned creative process fails to produce the desirable results because the environment, abnormal hygienic or other conditions are not conducive to productive mental work. A school teacher's timetable often has gaps between the lessons, and as a result the teacher needlessly wastes his time and unnecessarily tires. Sometimes, because of unsatisfactory examination schedules, particularly at higher educational establishments, some instructors have more work than they can do, while others do not know what to do with their time. Students either have to wait long for their examinations or are, on the contrary, rushed through their answers. And yet these "minor defects in

the mechanism" affect the efficiency of both the instructors and students alike and prevent them from properly utilising their time.

As we have already mentioned, the problems of rationalising mental work assume particular importance in the Soviet Union. The numbers of workers and collective farmers whose working hours are not confined to working at factories or in the field are growing with each passing day. They attend general educational evening schools, take correspondence courses in higher schools, and increasingly go in for the arts—music, singing, painting, dramatics, etc. Many workers and collective farmers devote part of their leisure time to inventions and to improving the work tools and labour processes.

Rational planning of their time is of tremendous importance to this category of mental workers, since it is usually limited. Work should be planned so as to give good results with a minimum of effort and expenditure of time and, what is more, to leave time for recreation. Such available labour-saving devices as the slide rule, various measuring instruments, tape-recorders, cameras for reproducing blueprints, etc., can be very helpful and it is a pity that worker-inventors who constitute a numerous army of mental workers are not always familiar with these instruments and use them less than they should.

What are the sources of our knowledge of scientific organisation of mental work?

In the first place, this organisation is based on an all-round study of the normal functioning of the human organism—its heart, blood vessels, respiratory organs and central nervous system—expenditure of energy which in each form of work has its own quantitative and qualitative characteristics and, lastly, nutrition, alternation of work and rest in mental endeavour, etc.

Some ideas about a scientific organisation of work may be gained from the study and analysis of the working day of great scientists, engineers, social and political figures.

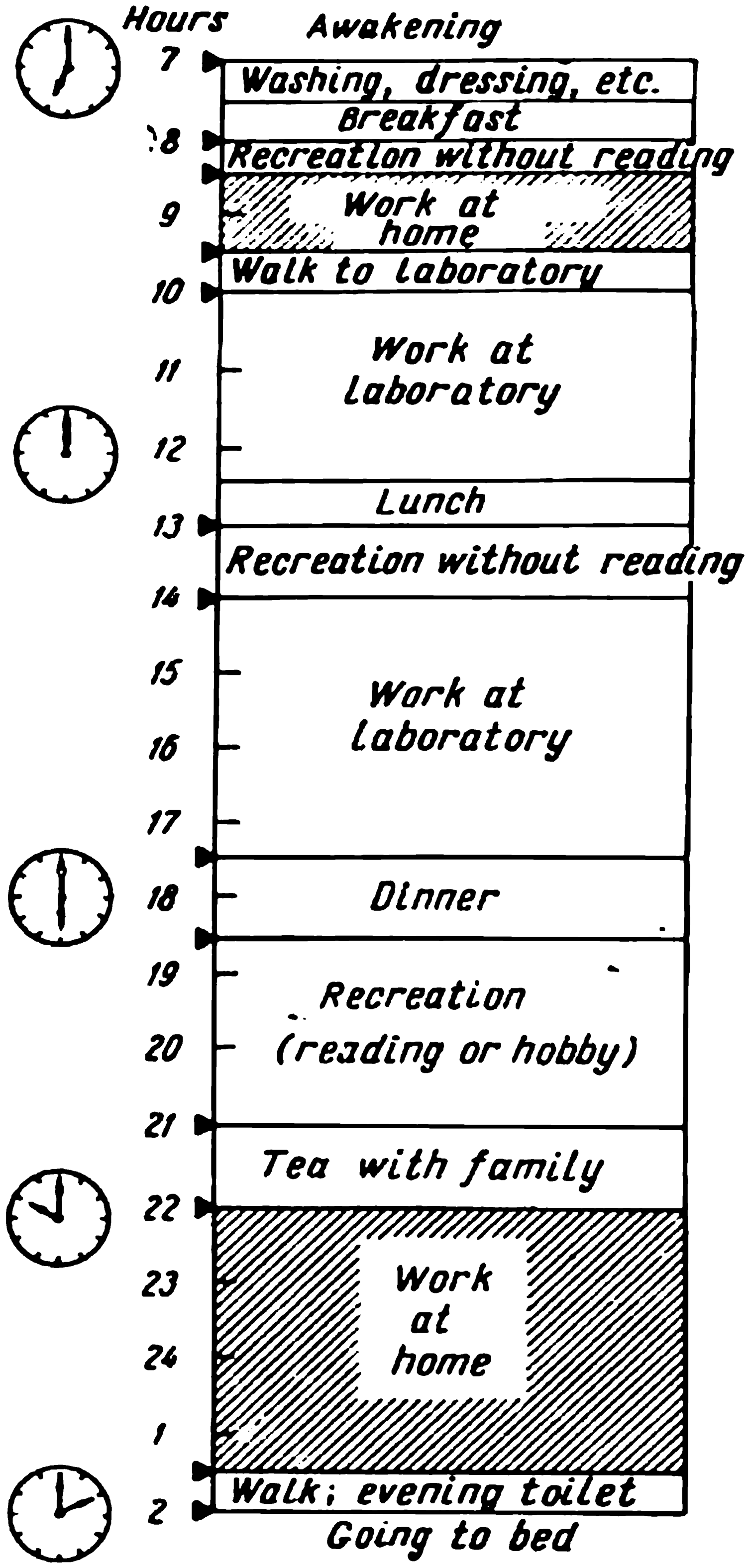


Fig. 31. Ivan Pavlov's working day

Marx and Engels owed their amazing efficiency to their highly rational working schedule.

Lenin organised his working day very rationally and economically. The founder of the Soviet state managed to study a tremendous amount of literature even while in exile and prison.

Balzac, Lev Tolstoi, Pavlov, Michurin and other outstanding writers and scientists arranged their working day very rationally (Fig. 31).

From the point of view of its organisation mental work is mainly sedentary; it requires staying indoors (sometimes for many years), often with inadequate ventilation and poor lighting. It also involves but little physical effort, as in writing, mechanical drawing and manipulating computer and other devices.

Mental work requires a greater supply of blood to the brain, which considerably increases the tone of the blood vessels. This is quite normal and usually causes no com-

plications. But irrational organisation of mental work may lead to hypertension. Hypertension affects mainly people of strenuous mental activity and is often very difficult to control. However, this disease can be prevented by relatively simple prophylactic methods based on a knowledge of the physiology of mental work. The chief method is prevention of haemostasia (stagnation of the blood).

The sitting posture usually assumed in mental work, especially with the body half bent involves a certain compression of the chest and, consequently, inadequate ventilation of the lungs (Fig. 32). This posture hampers the organism's oxygen supply and interferes with the normal blood flow in the abdominal and pelvic organs, for which reason the posture must, from time to time, be changed; it does well to rise every ninety minutes or

Fig. 32. Harmful habits hampering productive mental work. Arrows indicate areas of greatest muscular strain and compression of nerve trunks resulting from incorrect sitting posture

two hours and walk about the room, or lie back in the chair, with the legs outstretched, slowly exhale and then take a deep breath. The best prophylaxis in mental work, however, is systematic physical exercise, which prevents constipation, haemorrhoids, and other intestinal and gastric diseases. Since there are no broad massaging movements in the shoulder girdle and pelvis, as in physical work, the flow of lymph in the upper and lower extremities is disturbed in the sitting posture. Sitting in an uncomfortable chair with the table too high or too low, mechanically compresses nerve trunks of the pelvic and shoulder girdles, and, hence, sciatica and plexitis. Prolonged work with the hands, especially the right hand,

Fig. 33. Dmitry Mendeleyev at work

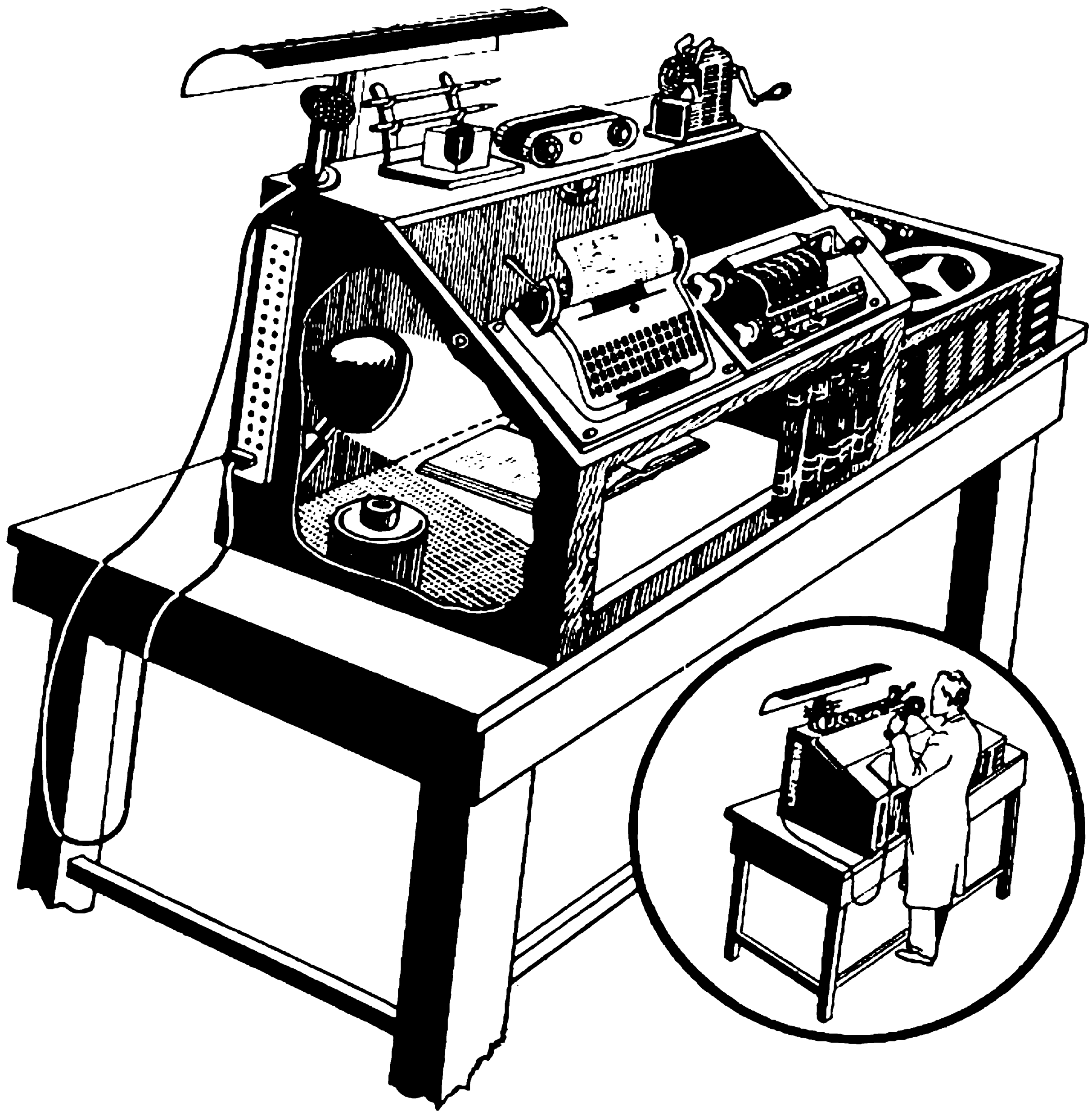


Fig. 34. Modern writing desk with built-in typewriter, arithmometer, camera, tape-recorder, drawing board, pencil sharpener and other devices (proposed by Y. Frolov)

often leads to finger cramps. This can be prevented by working with both hands, especially by using a typewriter, which is now within everybody's reach. It is a good hygienic practice to work standing (rather than sitting); Mendeleyev, Timiryazev and many other famous men used to work standing behind a tall writing desk (Fig. 33). We suggest the use of a specially constructed writing desk provided with luminescent lighting, a camera, tape-recorder, typewriter, arithmometer and other labour-saving devices (Fig. 34).

The eyes are the first sense organs to be affected by irrational organisation of mental work, because of incorrect or insufficient lighting and inconvenient position of the table and the objects on it. The source of light should be on one's left, the light falling on the objects of work and not directly on the eyes (the light must be shaded). Good lighting, frequent ventilation and short periods of setting-up exercises during work, systematic physical culture activities, including sports, morning setting-up exercises, silence during work, rationally spent Sundays, holidays and lunch recesses—all these simple measures are the best methods of preventing disease.

Diet is an important factor in mental work. The best practice is three meals a day at regular hours, which promotes good digestion. Eating dry food shoud be avoided. It is equally harmful to abstain from food during the day, thus simultaneously dining and supping at home three hours before going to bed.

Pavlov on Planning Studies and Scientific Work

In dealing with concrete examples of rationalisation of mental work we cannot envision all the possible cases likely to occur in the practical creative work of different intellectuals. Any attempt to supply ready-made recipes for fuller utilisation of the brain's inexhaustible resources, especially to indicate a "universal method of making discoveries" would be unpardonable levity.

Physiologists are still unable to give numerical expression to expenditure of energy in creative work, as it is possible in the case of physical work. All we can say is that mental work saves the energy, if not of the researcher, then at least of those who enjoy the fruits of his work.

While emphasising the importance of planned intervention of physiology in the organisation of mental work, we deem it advisable to quote Pavlov's testamentary letter to the Soviet youth who dedicate themselves to science.* In

* I. P. Pavlov, *Selected Works*, Moscow 1955, p. 54.

this document the great physiologist briefly and graphically defined the patriotic tasks facing the young Soviet scientists and those who aspire to become scientists, pointed out the ways and means to great attainments in any sphere of knowledge and warned against the many pitfalls on the path of a scientist. This letter is generally considered a valuable experiment in establishing a physiologically substantiated approach to rational organisation of mental work.

The draft materials for this letter, which we have collected, show that, while preparing the text of this letter containing advice to youths, Pavlov based himself on his teaching on higher nervous activity and the peculiarities of the second signal system of the brain. In indicating the three main principles which ensure success in scientific endeavour Pavlov offered his vast experience obtained in his laboratory and in his intercourse with intellectual workers in the course of his 65 years of fruitful creative scientific work.

According to Pavlov's teaching there is no essential difference between physical and intellectual workers. Under favourable conditions, anybody can establish new cerebral connections, i.e., elaborate conditioned reflexes of the second signal system requisite to scientific and any other work.

"Learn the ABC of science before you attempt to scale its peaks," says Pavlov with respect to organising mental work, namely, its *sequence* and *planning*.

In Pavlov's rough copies of the testamentary letter this requirement consists of several components which are obligatory for those who aspire to knowledge of the objects and forces of nature (natural sciences), or of themselves (psychology and the humanities).

First, Pavlov points out, science demands constant and persistent *concentration* on the object of study. When asked how he had made his great discoveries, Newton said: "By thinking of them all the time." This phenomenon

is related to another important method of research, *repetition of the experiment*, even if it is successful, to make sure of the results.

A scientist-to-be must strive to remove from his path all obstacles to the realisation of his idea, must not let himself be carried away by unproved hypotheses and must always respect facts. According to Pavlov, facts are the locomotive and hypotheses are carriages, and it is the locomotive that pulls the carriages and not vice versa. In the letter Pavlov said: "Facts are the air breathed by the scientist. Without them your 'theories' will be barren." At the same time there is need for *freedom* of scientific thought and an ability to give free rein to one's imagination. Faraday may serve as an example of this because, while working on electromagnetic induction, he advanced such bold hypotheses and performed such "inadmissible" experiments that he had to lock the doors of his laboratory so as not to be taken for a madman.

Pavlov pointed out the necessity of subjecting every discovery to a thorough test: "However fond you may be of your scientific idea, however much time you may have spent on its elaboration," he wrote, "you must give it up even if a single important fact disproves it. The important thing is not what you are trying to prove but what you are observing." However, this does not mean that one must become a "hoarder of facts". One must search for the laws governing reality, the laws governing matter; hence, the analysis of facts must not interfere with their synthesis, but the two must be reciprocally helpful.

It is essential to take note of all the *details* of an experiment, however small. No detail is too small for a scientist at his post. If a change in one of the many conditions of an experiment has led to a change in the result, it warrants some conclusion, but if two conditions are changed at once a conclusion is not warranted.

It is characteristic of every objective experimenter to doubt and dispute everything and revise his views if they

have proved erroneous. Pavlov mentioned this as a prerequisite for success in scientific research. At the same time the right to self-criticism should not be abused—one must be able to uphold and defend one's scientific views. Pavlov urged that the ideas of a scientist should be precise and expressed simply and lucidly. This short analysis of Pavlov's letter shows that his practice and theory were never at variance, that the latter helped the former.

Preparation for Work on Scientific Subject and Study of Literature

The propositions advanced in Pavlov's Letter to the Youth show the complex of behaviour acts which constitute adequate preparation for successful scientific work. Different authors (V. Weinberg, Y. Rozinsky, I. Rebelsky, S. Reinberg and others) have repeatedly dealt with the various stages of this work, but no scheme can as yet be considered final.

N. Vorobyov suggests the following plan of a scientist's work on the literary aspect of his research:

1. Introduction. Posing the general problem. History of the question. Present significance of the problem.
2. Division of the theme into separate questions and parts. Posing particular problems.
3. Factual material. Experimental and practical data and their comparison. Analysis of the facts.
4. Grouping of the factual material. Establishing logical connection between the facts.
5. Criticism of the theories and views which incorrectly interpret or distort the facts.
6. Exposition of the correct point of view. Proofs.
7. Generalisation. Establishment of laws.
8. Systematisation of the conclusions.
9. Synthesis of the parts. Solution of the general problem posed at the outset.

10. Conclusion. Prospects before science in the given field. Chief literary sources on the subject.

The process of research can be conventionally divided into the following stages: 1) general preparation for participation in research; 2) choice of theme, i.e., determining the content of the work to be done; 3) work on literary sources; 4) the researcher's own experiments (natural science is implied); 5) critical analysis of the data obtained; 6) elaboration of the material; 7) literary aspect of the work—preparing it for the press, a report, etc.

The researcher's personality shows itself in different ways at each of the stages, revealing the strength and weaknesses of his first and second signal systems.

Some young scientists would discard the age-old practical rules for preparation for creative scientific work. They choose their own ways, relying on the compensating powers of their young organisms. But violations of these rules, especially breaking the sequence of study and research, lead to lowered efficiency, mental overstrain and sometimes disorders of higher nervous activity, i.e., neurasthenia, psychasthenia, etc.

Scientific work is based on the activity of the second signal system.

The study of foreign languages without which any scientific—nay, any serious mental work—is now unthinkable, requires thorough analysis and synthesis in the sphere of abstract concepts, such as grammar, syntax, and, what is most important, an ability to bring every undertaking to conclusion. The important thing here is not so much the technique of translation (soon special machines will probably be used for this) as acquiring the "spirit" of the language, which embodies the history of the people, the carrier of the national culture.

The latter is connected with training the important function of generalising concepts, of abstract thinking, something young research workers are apt to forget, the oversight resulting in a "chlorotic" style. It also often

happens, however, that in pursuit of precise definitions of concepts the language of young scientists loses in vividness.

This applies even in greater measure to those who begin studying the philosophy of dialectical materialism which emphasises the general interdependence and interconnection of phenomena and the importance of both their analysis and synthesis. In this case the level of abstract thinking is still higher and the significance of strict *sequence* in the study of the material becomes still more apparent. One must not forget, however, that the best philosophers used graphic images. Neither should one lose sight of the history of science and the biographies of its great men. Every researcher should be well versed in the history of his subject; yet, some scientists think this superfluous and often waste their efforts on discovering already well-known truths and facts.

There is a peculiar dialectics here subtly noted by Pavlov. The fact is that in their pursuit of sweeping generalisations, in their eagerness to advance some hypothesis or other some mental workers completely disregard the rules and techniques of experiment, to which already Bacon attached so much importance. Instead of collecting facts by their own efforts they rely on the experiments and views of other people and lose their ability to observe reality, such as it is.

Hence, "self-organisation", the fostering of stable habits of persistent research and literary work, is not less important in preparation for scientific work than other preliminary measures, such as studying special periodicals. Even such habits as keeping regular records of one's activities (official duties, social work, studies, literary work, private affairs), drawing up daily schedules, keeping in order one's notebook and personal files are acquired in the course of long and systematic work and may be taught at school or the university (which, however, is not being done as yet).

As the first exercise in forming the necessary complex conditioned reflexes we recommend to keep a daily record of the most important ideas and observations from literary sources and one's own thoughts (these latter in a well-edited form). *Nil die sine linea* was the just demand of the ancients, and it remains just to this day.

Whatever the methods used in preparation for scientific research, the decisive factors is the *choice of theme*. The choice of a theme of scientific and social significance must display an element of daring and a readiness to make certain sacrifices in pursuing the aim; however, this is not always the case with young specialists.

Under the existing conditions the choice of theme depends on the scientific school, competent guidance and, of course, the scientist's own initiative. These factors offer a sure guarantee of originality of the work.

There are also efficient methods of studying *special literature*, which save the researcher from wasting his energy.

According to Pavlov, consistency in scientific work is connected with a strict pattern of actions elaborated in the nervous system, but the pattern is dynamic, plastic in the highest sense of the word. This is particularly evident in work with literature and applies both to content and form. One must not use one method, say, card indexing, today, and another—keeping notebooks—tomorrow. In general, notebooks, especially with entries made on both sides of the pages, are no good. In taking notes one must not fail to indicate the source at once, or one may get completely lost in the maze of the notes and expose oneself to an entirely undeserved charge of plaigiarism.

For a successful study of literary sources one must have index cards, such as are used in libraries, a box for the cards, well-sharpened black and coloured pencils, erasers, glue, scissors and sometimes a camera for copying necessary texts, drawings, illustrations, etc.

The fountain-pen cannot always be recommended, and

not because of any structural shortcomings but because its constant use may cause disturbances of the neuromuscular apparatus of the right hand. This is due to the fact that writing with a fountain-pen excludes the element of rest, involved in dipping an ordinary pen into an inkwell, and the extension of the writing hand. Hence, it is better to use an ordinary pen, and whenever possible a typewriter, typing with both hands.

The simplest physiologically expedient measure is to use (in reading-rooms) reading desks (like the stands used by musicians) on which the book is placed in proper relation to the visual axis of the eye.

In addition to the above rules for scientific work or public appearances, the following practical advices may be given, particularly to students.

1. Never sit down to work without a concrete plan and definite amount of work to be done; check the latter with the notebook and the calendar.

2. Never attempt to master and retain the material at the first reading, but have spare time to review the material.

3. Take your own notes of everything you are studying. Never use other people's notes.

4. Maintain connections between the subjects studied, between theory and practical work; study the experience of industrial innovators.

5. Wherever possible use graphs and curves which are good aids to memory.

6. Use narrow strips of paper with notes in coloured pencils to mark pages in books.

7. Never use stimulants (strong tea, cold shower, etc.) before examinations and never work at the expense of sleep. Do setting-up exercises in the morning and take a walk before going to bed.

8. Never fret at examinations, listen attentively to the questions and be correct without either trying to ingra-

tiate yourself with the examiner or assuming an air of arrogance; answer briefly and to the point.

9. After passing your examinations quickly switch over to public duties, reading, sports, hiking, etc.

10. Make yourself familiar with the new literature in your field, but never neglect your textbooks; preserve them to compare the old data with the new by marginal notes, (inserts, photos, etc.).

Peculiarities of Lecturing and Planning Lectures

Mental work usually implies work in the laboratory or literary endeavour (dissertations, magazine articles or monographs prepared for publication). But planning oral reports, lectures and the like requires as much attention as the work of experimenters.

A popular-science lecture or a report constitute a peculiar type of literary work but many of the oratorical devices which have been elaborated during the centuries of juridical practice will benefit students, university instructors and anybody who has to speak in public.

What determines the success of a report or lecture delivered to an audience? Why are some speeches remembered as long as one lives, while others are forgotten the next day? We feel that these questions should be discussed here. And if we succeed in answering them we shall have raised a corner of the curtain that hides the theory of the art of public speaking, the art of lecturing.

Some people doubt that such a theory exists and that it can even be developed on objective scientific basis. Others think this question irrelevant, because they consider eloquence a gift of the gods, one granted to man very rarely and beyond man's knowledge. Still others hold that delivering lectures is a mechanical art, that it can be mastered by practising and making use of a few necessary devices and requires no inspiration. All these opinions are equally wrong.

We feel that Soviet science, particularly the experience of lecturers in Soviet time, warrants our assertion that a theory of lecturing does exist and that lecturing is serious creative work which is neither mechanical nor a result of pure inspiration.

What are the physiological and psychological foundations of the art of lecturing? We shall consider a few of them.

The first requirement is good knowledge of the factual material pertaining to the subject at hand. The speaker must be well versed in all the achievements of the branch of science he is dealing with, as well as its history and prospects. The material at the command of the lecturer must exceed manyfold that which he is presenting in his lecture. An audience is quick to distinguish such lecturers from those who know only as much as they say. This part of the lecturer's skill is felt in the assurance with which he draws up his plan and in his use of apt illustrations from actual life. A lecturer must not limit himself in this respect by saying to himself beforehand that he will state only two or three facts as he may not have enough time for more: sometimes a vivid image or felicitous expression enables one to say more in one minute than under other circumstances in half an hour.

I well remember a lecture by Mendeleyev entitled "Learn to Know Russia". We, his listeners, who were all young at the time, were overwhelmed by the torrent of ideas he let loose on us in the course of an hour and a half. It was a manifestation of the wealth of his inner world. Mendeleyev cut the outlines of Russia from cardboard, stuck a pin in the centre and showed it to his audience. We were all persuaded that, as regards the working of her natural resources, the centre of Russia should not be in St. Petersburg, as Leningrad was then called, but in Siberia, somewhere near Novosibirsk. And now, sixty years later, we see our industry moving eastwards in the direction he indicated.

In Mendeleyev's lecture facts crowded each other, collided, followed each other in swift succession, and the audience sat listening with bated breath, although from the viewpoint of the limited capacity of attention this wealth of ideas may be said to have been presented irrationally.

While listening to another lecturer, the famous composer Rimsky-Korsakov who also was alive in the days of my youth, I felt that his method of proving his point was like music (for it is only in music that you find such a harmonious combination of the separate parts) and that his lecture was built on the contrapuntal principle. It was a brilliant lecture of a true scientist rather than of a mere musicologist.

I have also heard Pavlov speak, but his art of lecturing was of an entirely different kind. He may be said to have been talking with his audience, for he asked questions and answered them himself. It was more like a dialogue than a monologue. His speeches were also amazing for the wealth of facts he cited but the facts did not merely form a single file; they seemed to clash. His lectures, even those he delivered to his students, rather resembled acts of a drama, or scenarios, in which scientific ideas and abstract concepts conflicted, collided and disengaged. Analysis was followed by synthesis, then came the denouement—and the conclusion, the only possible conclusion, emerged before the marvelling audience.

Such are the different ways and means by which lecturers achieve the same aim—riveting their listeners' attention to their subject. You remember such lectures as long as you live.

A second requisite of the art of lecturing is firm scientific convictions, the possession of a distinct personality, of one's own "voice". It is not enough for a lecturer to like addressing an audience, although this is very important for his success. He must also be convinced of the correctness of his scientific views and must uphold them. In a word, if a lecturer is to be successful he must love his

subject and have a sincere respect for it. An audience always feels when a lecturer is convinced of what he says, is passionately interested in his subject, rather than is merely "speaking on the subject".

A third requirement is that the lecturer should keep close to life, to the practical problems of today and should strive to see the future of his science. But the closeness to practice and the concreteness of the material presented must be intimately connected with the theoretical aspect of the given problem. This is perhaps the most essential characteristic of a good lecture and implies an ability to present abstract concepts (for any lecture necessarily contains a number of abstract concepts) as graphic images or to tie them in organically with those the audience already has.

Another factor contributive to success in lecturing is *brevity*, the use of short phrases without high-flown words. One must not strive for the eloquence of preachers or certain lawyers and must not use too many foreign words, but rely mainly on the resources of one's native tongue and preferably draw on one's national classics. All this repuires a lot of training. Of course, a lecturer needs a modicum of emotionality and passion, but this must not be artificial. Deliberate emotionality not only fails to win the audience, but even estranges it. Only the ability to show how scientific facts come into being, how they develop and how some ideas contradict or confirm others can impress an audience.

Last but not least, one must respect one's audience, whether it consists of academicians or school children. An audience may be addressed very politely as "This Respected Assembly" or "Dear Friends", but this does not in itself denote real respect for it. The respect for the audience must be manifested in the lecturer's belief that the listeners crave for knowledge and are able to understand what the lecturer is saying. And it is a good tradition that

requires the lecturer to remove his hat, even if he speaks in the open.

A still unsettled question is whether a lecturer should read from a paper or speak as though extermpore. This question is also connected with the theory of the art of lecturing, today *speaking* is winning greater favour than reading. The question must be settled with a knowledge of psychology and physiology of attention. Although formally a lecture read from a paper and one delivered without the aid of a paper may be identical, the one read from a paper will often fail to produce even half the intended impression. Hence, this question does not admit of formality, and each individual case must be decided on its merits.

Why does a lecture delivered without the aid of a paper tend to raise the lecturer's prestige, while reading it detracts from its value (except in the case of very important political speeches, as for instance, at international assemblies)?

A printed word can be re-read, a newspaper article can be cut out and filed, but a spoken word cannot be filed, nor can it be returned on the listener's initiative. That is why the listener reacts so differently to the spoken word and the word read from a paper. Moreover, while following the speaker's living word the listener seems to participate in the development of his ideas.

The material presented by a lecturer must differ somewhat from that found in books where there is a peculiar choice of words and a peculiar structure intended for repeated reading.

Freely-flowing, precise, graphic speech with varying intonations will stimulate the listeners' attention. From the physiological point of view, it maintains the orienting reflex for a longer time.

The lecturer's whole behaviour, the rhythm of his speech and all his emotions must be used to elicit a similar rhythm and emotions in his audience, to make it think together

with him and share his ideas. If the lecturer has achieved such unity with his audience even for a short time, the lecture will produce a considerable effect. Besides, every lecture, even if repeated from year to year, must have its own individuality. Stanislavsky used to say that even the hundredth performance of a play must in some way differ from the ninety-ninth. He adjured his actors not to grow stale. This arises from the very essence of human psychology. The hundredth performance at the theatre and the hundredth lecture are attended by new audiences; the lecturer sees different people before him and he, too, is in a different mood. He has read new material in the interim and, although he has a fixed text, he ought to vary it rather than read it as though it were a verbatim report.

What does concreteness of the material presented to an audience imply? It implies that a person addressing an audience is expected to link theory with practice, with life. One may cite a host of facts accompanied by figures, diagrams, calculations, etc., but such concreteness soon begins to pall. A lecturer must make very careful use of figures. To hear some ten or fifteen long figures at a stretch is too much of a neuropsychic strain, and there is a danger that the audience may say: "We'd rather read all this in the newspapers."

It would seem that quotations tend to make a lecture more concrete. Of course, one must express other author's ideas in their own words, but if there are too many quotations the audience's attention will begin to wander. There are many ways of introducing the element of novelty into the treatment of a subject: one may cite new facts connected with the present or may use new methods of presenting the material; each lecture must contain something new that fits in organically with the whole. It stands to reason that, to include new material in his lectures, a lecturer must have good knowledge of his subject and must watch its development.

It is a great drawback to a lecturer that he does not

always know beforehand the composition of his audience and, consequently, does not know what is likely to interest it. This affects any lecture, however it may abound in new facts which in themselves are apt to interest an audience.

A lecturer's ability to excite the interest of his audience is sometimes apparent from his first words. This ability forms one of the foundations of the art of lecturing. A lecture may be begun with some incident taken from everyday life which can be utilised to introduce a series of abstract premises which constitute the body of the lecture.

While the first aim of the lecturer is to attract his audience's attention, his second aim is to hold it. The attention is held, in the first place, by setting definite limits to the subject under discussion. For this purpose it is well to define the scope of the lecture, for one cannot cover everything.

Thus, the first important factor in a lecturer's relations with his audience is novelty to attract the audience's attention, the second factor is organisation of the audience's attention and the third—transfer of the engaged attention to the main factual material, which forms the subject-matter of the lecture, and leading the audience to inevitable scientific conclusions.

Our discourse on lecturing will be incomplete if we do not mention inspiration or *intuition,* an element which is also a constituent of a teacher's or public speaker's art. Inspiration, which appears to have little to do with planning mental work, raises the skills to the highest level, improves the work of the second signal system and prevents fatigue.

It is but natural that the problem of intuition makes one wary, for it may imply some supersensual knowledge of the world! Actually, from the standpoint of modern physiology and materialist psychology, intuition in scientific work refers to the function of the brain under incomplete

concentration of the excitation processes in some of its parts. It is in these "half-shaded" zones that ideas and surmises, not yet tested by practice but often very important, are born. Somewhat inhibited and beyond the sphere of our consciousness, they, nevertheless, serve the creative purpose as well as do the intensely excited main cells and centres.

According to Pavlov, any intuition, including scientific intuition, is a function of the brain, but a special function that is performed under conditions somewhat differing from those of previously thought-out, conscious acts. Just as in the first signal system of the brain, a happy temporary connection between centres is sometimes suddenly formed in the second signal system, and a new idea or conjecture that should be caught "on the fly" is thus born.

There is, consequently, nothing supernatural about intuition, for it is a function of the brain, just like other reflexes and associations, but taking place under somewhat special conditions. Happy ideas sometimes occur not at moments of concentration, but during interruptions in work, recreation and general relaxation. But a man of science must not rely on this as a system, for it is rather more suitable for artists.

One more warning: a lecturer must, above all, avoid boasting even if he has real achievements and extensive experience and has made a considerable contribution to science. He must avoid setting himself up as an example to follow, for this is a sure way to lose the audience's respect.

The art of lecturing, like any other art or skill, requires extreme *self-discipline*. While soaring on the wings of his ideas a lecturer must be careful not to overstep the boundaries of modesty and simplicity in presentation.

A few words about improvisation. Improvisation and inspiration are not the same thing, although inspiration often makes one improvise. The Academician O. Schmidt's thirty lectures delivered without any reference materials

on a variety of scientific subjects, while he and his comrades from the *Chelyuskin* were on a drifting floe, are an outstanding instance of improvisation. Luckily, Schmidt had been an editor of the first edition of the Big Soviet Encyclopaedia and had a marvellous memory. These improvised lectures did much to boost the Chelyuskinites' morale during the hard days of the drift.

The *structure* of a lecture, its plan, its sort of blueprint is the corner-stone of the art of lecturing. It should be remembered that a plan, which makes a lecture a complete entity, is vitally necessary. The audience does not have to know the detailed plan of the lecture in advance, because this lowers the interest in the lecture. Each consecutive part of the lecture should be somewhat of a surprise. The lecturer must lead his listeners from one point to another without, however, revealing the mechanism of its construction. In some cases the lecturer may say in the middle of a lecture "there is still this and that for us to discuss", in order to stimulate their attention and prevent fatigue.

The plan (which the lecturer draws up for his own use) should be divided into several parts, depending on the content, for this facilitates the timing. Like the plan for any work, the plan of a lecture does not take shape all at once, but is a gradual process, during which it may be repeatedly altered, the individual parts changing places, etc., until the lecture is integrated. Only then is the plan ready and the lecture can be delivered to an audience. But in the future the plan may be changed many times again, for no plan can be regarded as final. Even if one has delivered a lecture a thousand times, one will find, the thousand and first time, something to change, either to omit or add, depending on the expected composition of the audience, the altered conditions and one's own deeper insight into the subject.

Essential and Non-essential Differences Between Physical and Mental Work

The division of labour into physical and mental arose together with the appearance of private ownership of the means of production. In the Soviet Union this division, this contradiction is now being eliminated.

Although the classics of Marxism had already laid the foundation for the theory of effacing the essential differences between mental and physical work, in its practical aspect this problem arose before us recently, when the socialist countries, the U.S.S.R. in the first place, started building the economic basis of communism, fulfilling the Seven-Year Plan for the development of the national economy and introducing a system of universal polytechnical training.

The gap between physical and mental work is being filled at factories and plants in the way envisaged by the founders of Marxism-Leninism. Industrial and agricultural innovators, inventors and rationalisers now often publish booklets describing their experience. Formerly this was the province only of specialists who were not directly engaged in production. Today the best workers consult professors and engineers. Although the differences between the work of a chief engineer and a machine operator are still essential, the differences between physical and mental work are being noticeably effaced.

The industrialisation of agriculture based on new socialist principles and new agronomy (Fig. 35) has played a very important part in eliminating the contradictions between mental and physical work in this field. Until recently the people of the countryside were engaged mostly in hard, exhausting physical work which retarded the mental development of many millions of people.

Without the active participation of the peasants industrialisation could not solve the problem of eliminating the contradictions between mental and physical work, be-

tween industrial and agricultural labour. In the Soviet Union and other socialist countries where the peasants and workers are masters of their states the former not merely receive an agronomical and general education but even vie with each other in advancing the science of agronomy. By their collective efforts they subject the theories of agronomical science to practical tests. The participants of the emulation movement share their experience with other front-rank peasants, render comradely assistance to collective and state farms which are lagging behind and inspire them with their own enthusiasm; this is unthinkable in capitalist countries where each man is only for himself.

Fig. 35. Changes in the nature of agricultural labour in a single lifetime

Signs that the formerly inevitable differences between the two types of work will soon be eliminated are particularly evident in the practice of the *Communist Work Teams* where the striving to study, improve the working methods and raise the labour productivity by reorganising the production process are most clearly manifest. Every member of such teams participates in the common work creatively rather than merely fulfilling his assignments. The division of labour in Communist Work Teams contributes to the development of scientific ideas which tend to

improve production; here work is harmoniously combined with a high sense of social duty.

The new stage in the production relations reached in our days is contributive to a rise in the productive forces of society and fosters a communist attitude to labour. A characteristic example has been set by Valentina Gaganova who transferred from a foremost to a backward team in order to advance the latter, although this temporarily lowered her earnings.

The movement to organise Communist Work Teams is closely connected with the increased yearning of the working people for industrial efficiency and general culture. Formerly the latter was the privilege only of the bourgeois intelligentsia. The Soviet working people are endeavouring to reorganise their everyday life, to do away with the survivals of the past such as alcoholism, superstitions and neglect of their living and working conditions, which was responsible for many occupational diseases.

In this connection physiologists and hygienists have much to do in the future. The greater demands made by the working people of the environment where the new, more complex, production process is to take place must stimulate a stream of suggestions from physiologists and physicians who are elaborating the problem of making working conditions, for all the complexity of the production process, still safer and less fatiguing, of rationally organising not only work, but also recreation, especially amateur art activities. The need to engage in creative activity is intimately associated with the desire to develop one's personality to the utmost. Thus the communist organisation of work in the teams does not mean a levelling of individualities or doing away with personal initiative, but the fullest possible development of the human personality.

Corrective Physical Exercise for Intellectual Workers

Proper and systematically performed physical exercises, as well as rational everyday life and recreation which re-

sult in a gradual build-up of the health constitute a potent means of raising the working capacity of young and, especially elderly people engaged in mental work.

There are still very few mental workers who go in for physical culture and sports, although their number among scientists is considerably increasing.

Middle-aged and elderly men and women—the period of creative maturity—do not need all types of physical exercise, but only those that are likely to benefit their nervous system and will not overstrain the cardiovascular apparatus.

The exercises for elderly people are not particularly attractive and do not produce the aesthetic impression of those performed by young gymnasts at exhibitions. They are very important, however, and playing a big part in everyday Soviet life, they are destined to help the elderly people in their fight for better health.

In the U.S.S.R. physical culture is part and parcel of the health protection system and a must in everyday life. It is a factor which contributes to longevity, enhances efficiency and comes under the province of *gerontology* (scientific study of the phenomena of old age).

Mechnikov was one of the first to suggest staving off old age but he did not take into account the social angle of the problem, by far the most important in the present instance, i.e., the right to work and to rest, which are not guaranteed in capitalist countries.

Soviet gerontology associated with the work of A. A. Bogomolets, Z. G. Frenkel, V. V. Gorinevsky and A. S. Nagorny is based on progressive materialist science.

Positive emotions are very important, for they also determine success in physical culture and sports activities of mental workers. A person who has at least once experienced the joy of "overcoming the imperfections of one's nature", who has been able to subject his motor impulses to the common rhythm of collective movements (collective physical exercises should be done to music by

both young and old) will feel increasingly attracted to physical exercise and, subsequently, to sports, hiking, outdoor games, etc., with a marked improvement in health and efficiency.

Positive emotions are conducive to success in all spheres of work and sports. This is what is meant by being in good form.

A person who neglects physical exercise is not only deprived of the joyful emotions provided by bodily exercise, but his brain also receives a host of abnormal signals from the working organs. He feels "a pricking sensation in the heart", "heartburn" and a "gnawing pain in the liver". All such sensations disappear with systematic exercise.

Some think that training the motor apparatus, which involves mobilisation of the reserve forces of the nervous system, is proper only for the youth and wrong for middle-aged and elderly people. This view is incorrect because the appearance of grey hair does not mean that the nervous system has lost its plasticity or that the motor analyser has become incapable of improving. By his personal experience Pavlov proved that physical exercise (considering age peculiarities) can be taken by people even past 80 years of age.

The experience of physical culture physicians and workers shows that the muscles and the nervous system intimately connected with them are still highly capable of exercising in both men and women past 45 and even 50 years of age. Many of the organism's defensive forces can be mobilised through the corresponding reactions of the brain's motor analyser even at a later age. It is only a problem of the best method to be employed in physical exercises for the oldest group of people.

Besides the valuable contingents of elderly and old intellectual workers whose health requires particular care and who need special physical exercises, there are no less valuable intellectual workers between the ages of 35 and

40 who also need regular exercise to safeguard their health so as to be always fit. To impede the development of the changes which are inevitable with the coming of old age, physical exercises must be performed systematically.

The aim of correctly understood mass physical education practised on an increasingly wide scale in the U.S.S.R. is to develop all the sense organs, from the muscular sense to the higher cerebral systems, maintain discipline in work and establish certain achievements in sports (naturally, without setting any particular records in the case of middle-aged persons).

A good example is the physical culture group of old-age pensioners who attend special gymnasia in the Bauman District of Moscow.

Physical exercise at any age must not be limited to morning setting-up exercises, beneficial though they are. Lenin was of the same opinion: we learn from one of his letters to his sister M. Ulyanova that he enjoyed exercising before going to bed and found this practice beneficial.

Evening exercises for relaxation recommended by some physicians, and better still, regular walks before going to bed, help the organism, especially in the case of mental workers, to relax and enhance efficiency.

Any system of physical exercises must be supervised by a physician.

This is particularly necessary in cases of middle-aged and elderly people, people who have recovered from serious illness and women during certain periods of their life.

The choice of the exercises from among those offered here must be made and the repetitions of each determined by a physician well versed in the technicalities of physical culture. What is good for a thirty-year-old athlete cannot be allowed one aged sixty, and this especially applies to the number and speed of the exercises.

Very strict medical supervision is required in the case of persons with heart diseases, even compensated, those

who have had myocardial infarction, however slight, and also those with organic liver, kidney and central nervous system disorders, vascular spasms, aftereffects of concussion, etc.

Light physical exercise under medical supervision is indicated in cases of pulmonary diseases, rheumatism, and affections of the alimentary tract manifested in constipation.

Medical supervision does not preclude self-control; while a physician can examine each athlete no more than once a month, one can study the effect of physical exercise himself. Counting the pulse before and after exercise will show the intensity of the effort. If the pulse is too fast after exercise (more than 90-100 beats per minute) one must ease up the following day, or even take no exercise for a day or two, after which the exercises must be made less strenuous.

Taking one's pulse is not all. Those who go in for physical culture must keep records of their efficiency on exercise and non-exercise days, of their sleep (deep or light), ease of falling asleep, headaches, fitness upon awakening, appetite, bowel movements, irritability, equanimity, etc. All these criteria will show a thoughtful observer whether or not his system of exercise is correct. Those who take physical exercise must keep regular records of all the aforementioned criteria of self-control and the types of exercises used. Within a month or two it will be easy to see the increase in the individual's strength, agility and endurance. The physician will only have to check and confirm the athlete's observations.

Morning exercises must always be accompanied by elementary hydrotherapeutic measures and massage. This follows from the physiology of exercise and is an excellent supplement to exercise.

Massage (and self-massage) strongly recommended to all athletes, as well as mental workers, is easy to perform. All the movements, such as rubbing, stroking, etc., are

performed along the lymphatics and veins; on the extremities, from the phalanges towards the shoulder and pelvis. The massaged extremity must be somewhat relaxed, raised and comfortably placed on a chair. Massaging the abdomen is very effective, the kneading and stroking being done in the sitting posture so as to influence the surface only and not affect the inner organs. Massage of the neck is also beneficial but it should be done with caution since important vessels and nerves run to the head near the surface.

All physical exercise must be taken on an empty stomach or not earlier than one hour after eating. Some people would do well to perform certain exercises before going to bed, but fewer in number and at a slower pace.

Breathing Exercises

Elderly people, especially intellectual workers, must devote considerable attention to breathing exercises. As a rule, books on corrective exercises and common medical practice underestimate breathing exercises or treat of them by means of don't's as "Do not breathe deeply without corresponding muscular work" (Krestovnikov), "Do not hold your breath at the level of inhalation", etc. This is not enough. Everybody knows now that breathing exercises are very beneficial and that they must be accompanied by natural movements, for example, extension of the body during inhalation, flexion during exhalation, etc.

Correct breathing is necessary for good swimming, walking, track and field athletics, sports, etc. But the importance of correct breathing for mental work is still grossly underestimated. Only teachers of singing and sometimes elocution demand that their pupils should master the art of breathing, and even then their demands are not always complied with.

Much has been said in scientific literature about breathing exercises and massage, another process closely related to them, but the subject is far from exhausted.

The experience of eastern, particularly Chinese, medicine and physical training introduces an important corrective into the methods of breathing exercises treated in both West-European and Soviet literature. The observations of Chinese specialists have long been unknown to their European colleagues. Although their systems of exercises contained many outdated traditions and even mystical beliefs (for instance, the demand that the hair and fingernails should not be cut during the course of treatment with breathing exercises), physicians in new China are revising the theoretical foundations of the ancient national forms of physical culture and find that they meet many of the requirements of materialist physiology. Of particular interest is the fact that some systems of breathing exercises are meant for the aged. Liu Kuei-chen ties his work in the field of pneumotherapy with Pavlov's physiological views on the organism and Mechnikov's theory of ageing. It is very important for us to bring to light all that is valuable in the age-old experience of Chinese breathing exercise and utilise it to safeguard the health and raise the efficiency of intellectual workers.

Liu Kuei-chen confirms the necessity of inhaling slowly and through the nose.

During a correct inhalation the thorax considerably rises and expands, the diaphragm flattens and the lower part of the abdomen is drawn in. Anyone can verify this by placing the palms of one's hands in the iliac region and on the lower part of the abdomen.

Chinese breathing exercises involve not only the muscles of the thorax and the abdomen, but also those of the extremities, the hands and toes (this has been practised in Europe as well) and finally, the muscles of the tongue, lips, nose, the eye, the lids, cheeks, larynx, etc.

The inhalations and exhalations are counted mentally, special attention being paid to the pause between exhalation and inhalation and the length of time the breath is held during inhalations. With every exercise the breath is

held for a longer time, i.e., until it is as long as the state of the organism (that of the cardiovascular system) will allow.

In China the therapeutic effect of breathing is enhanced by certain postures, such as laying on one side with the upper leg flexed, sitting cross-legged with the palms of the hands held together on the bottom of the abdomen and pressing on it during inhalation.

Depending on indication, therapeutic breathing exercises last *a few score minutes* (in the U.S.S.R. from two to ten minutes) and in the case of sick persons up to 3 or 4 hours a day (with intervals). Whatever the duration of the breathing exercises, each successive inhalation must be deeper than the preceding one; when the greatest depth is reached, the inhalations become gradually more shallow. This produces a tranquillising effect.

Modern Chinese physicians specialising in therapeutic (and preventive) pneumotherapy now combine breathing exercises with daily massage of the skin in the morning: during washing the skin of the face, breast and neck (which is very important), arms, legs and the abdomen is massaged. The inhalation is accompanied by stroking in one direction, exhalation—in another. A peculiar relation has been established between repeated rubbing and stroking of the skin of the foot and the state of the mucous membrane of the nose (prevention and treatment of catarrh), and even of the heart vessels. It is quite clear that where the heart is concerned there must be strict medical control.

Another important requirement is that the person who, in addition to other exercises, also practises breathing exercises should during the session isolate himself, detach himself, as it were, from his surroundings. This is dictated by the desire to direct the patient's attention to reflexes of the vegetative nervous system without, however, exaggerating his subjective sensations. This requirement has a certain physiological justification. Concentrating attention

on one object facilitates to a certain extent concentration of excitation at one point of the cerebral cortex accompanied by inhibition in its other parts which were too busy during the day. It should be noted in general that breathing exercises, as well as the massage we have just described, are conducive to "internal" training of the nervous system and are effective in combating insomnia without the use of hypnotics which are far from harmless, especially for intellectual workers. The Chinese author says that the exercises, once begun, must not be stopped before a state of complete sedation has been achieved. This holds good for all other types of physical exercises and should not be forgotten by those who organise setting-up exercise periods at industrial enterprises and offices.

It is worth mentioning here that many European and American authors (in the U.S.S.R., O. Lobanova, Y. Popova and others) employed similar methods of breathing exercises to obtain excellent results in preventing and treating cardiovascular and other disorders. The experiments of these innovators in medicine, however, met with an opposition on the part of adherents of "classical" medicine and physical culture. This problem should be further investigated by means of modern physiological apparatus.

The respiratory function is most intimately associated with the cardiovascular. The connections between the work of the heart and that of the lungs are so close that physiologists often refer to the cardiopulmonary apparatus. Any disturbance in blood circulation interferes with gas metabolism and vice versa.

The condition of the heart in various types of muscular work is best judged by the frequency and manner of contractions of the heart muscle. This determines the supply of blood to the working organs, and consequently, of oxygen to the tissues, as well as the removal of carbon dioxide and other metabolites accumulated in the cells.

The general index of the work done jointly by the heart and blood vessels is the maximal arterial pressure. The

organism strives to preserve this pressure as far as possible on a constant level. At the same time the arterial pressure is immediately affected by emotional states. That is why excessive physical and prolonged emotional strain affects first of all the cardiovascular system, leading to hypertension or hypotension, both equally harmful to the organism. Physical exercise prevents these two diseases.

* * *

Hence, in addition to a rational diet, sound and refreshing sleep and certain morning hydrotherapeutic procedures, well-organised and varied creative work is a *sine qua non* of good health and a sure guarantee against any sickness.

Every Soviet intellectual past forty ought to have a "second" occupation such as gardening, or work at the cabinet-maker's bench. Bookbinding is a good hobby, or, if one likes being on the move, one may become a hiker, amateur photographer or film-maker, shoot, hunt or angle, thus spending a good deal of time outdoors.

A "third profession" that has persisted through centuries is bringing up children, sharing their interests and, upon reaching physiological old age free from disease—which is the aim of Soviet health protection—participating in rearing one's grandchildren.

All the above formed the basis for the tremendous mental productivity of such brilliant men of our time as Lev Tolstoi, A. N. Butlerov, I. P. Pavlov, I. V. Michurin, Rabindranath Tagore, A. N. Bach and N. D. Zelinsky. They combined mental work with manual, to which they had a creative approach. Incidentally, many outstanding scientists and cultural workers lived to a ripe old age and had large families.

A most instructive example is the working day of Pavlov, whom I knew at the time of his strenuous creative work. He spent six hours every day in the laboratory and worked

four and a half hours more on books and MSS in his study, which makes ten hours and a half—and that at the age of 85!

Working periods alternated regularly with rest and recreation periods, for which $3^1/_2$ hours were set apart. In the summer Pavlov liked to spend his free time in the garden and play *gorodki (see* Fig. 31).

The Soviet state takes care of the health of the working people; it improves the working and living conditions and provides rest and recreation facilities. It is up to us to make the best use of these facilities during our holidays and days off, by spending them rationally and with benefit to our health. The best way to preserve one's health and the efficiency of the nervous system is to plan one's work as well as one's leisure time.

CHAPTER NINE

AIDS TO MENTAL WORK

"Bibliographical Combine" and Other Aids Used in Mental Work

Until recently the systematisation of knowledge in different branches of science and organisation of reference in the Soviet Union took the shape of reviews or catalogue cards in libraries (with or without brief annotations) where the elements of information, such as the title of the book, or article, year of publication and summary of content were listed in a certain order.

But now that hundreds of scientific works appear annually in all languages this method of systematisation is inadequate, for looking through the cards takes too much time.

For quick reference a machine has been invented with a photocell on which light falls through a film each frame of which bears data pertaining to a book or an article (Fig. 36). How does this library machine work? Every frame is divided in two parts, with the title and sometimes the annotation in the left part and a fine network of small squares in the right; the combination of the squares corresponds to the catalogue card number of a particular branch of science (in libraries a catalogue card number is made up of letters and figures). That same catalogue card number is traced on another film of the same size

in similar squares but in an inverse manner, that is, all that is black on the first film is transparent on the second and vice versa. When it is necessary to select annotations dealing with some branch of science, for instance, magnesium oxides or nucleic acids, the second film called the standard-order, is placed against a photo-relay connected

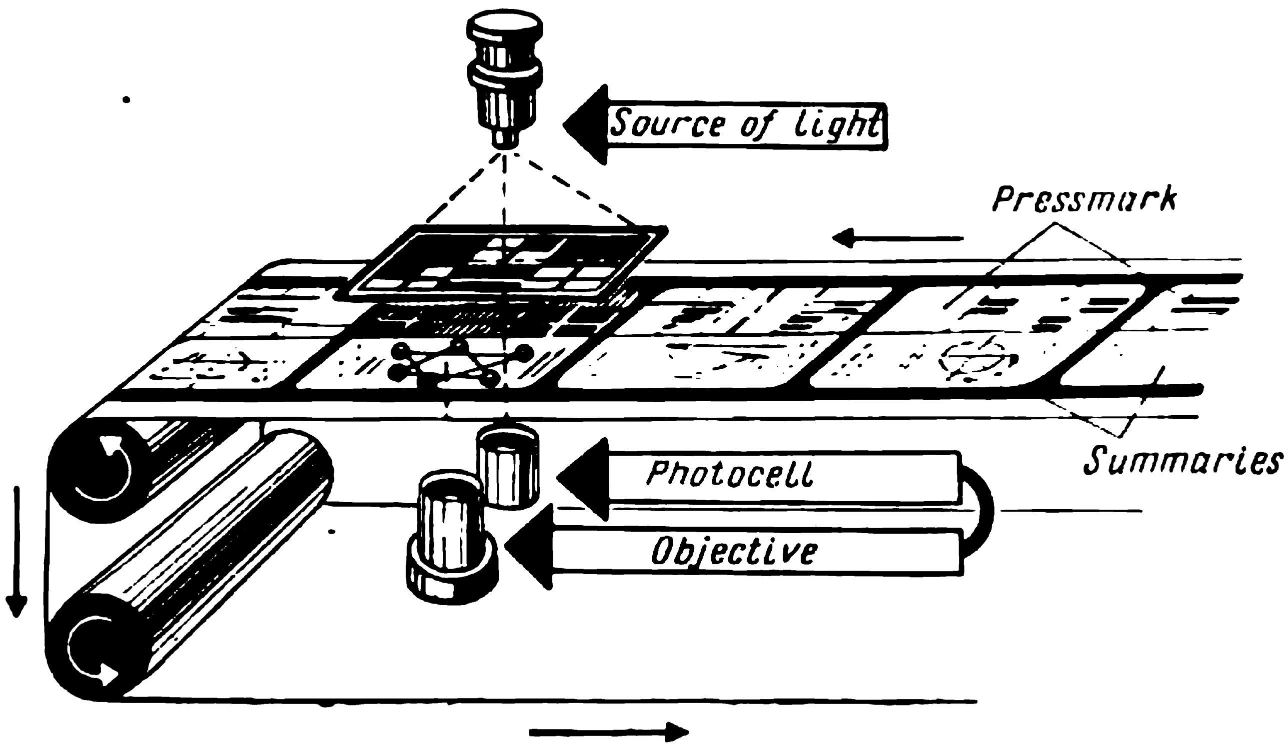


Fig. 36. "Bibliographic combine". Photographic device (left) for quickly obtaining information bearing special catalogue card number (right)

to the shutter of a camera and the film with the titles is run at a rate of 10,000 frames a minute. As long as the squares do not coincide completely the shutter does not work. But when a coincidence occurs, i.e., when the annotation deals with magnesium oxides or nucleic acids, a click is heard, the photostat produces a microfilm which can be enlarged at once. So within some ten minutes one can obtain all the literature published in the last few years. Formerly, it would have required several months to obtain this information.

This is a new progressive method of organising bibliographical information, which we owe to photography and electronics engineering, to what is known as the electronic eye. However, we shall beware of using such terms, because the relationships between the organs of the body and work tools cannot be explained by the simple, even if obvious, analogy—the human eye and the eye of a camera.

We have given a concrete example from the work of these original machines in order once more to illustrate in conclusion the peculiarities of the human brain's creative work and to show that the developing technical environment with its multitude of machines is becoming more intricate by acquiring ever new devices. We mean the new science of cybernetics which has facilitated mental work to the same extent as classical mechanics facilitated and modified physical work. The word "cybernetics" found its way into technical vocabulary and then into everyday language about fifteen years ago. Today much is being written about its attainments, new machines are being designed and problems of cybernetics are discussed at international conferences.

Cybernetics (from Greek *kybernetes*, a helmsman) is the scientific study of control and communication mechanisms. It has revolutionised many branches of industry and construction and has made it possible to control at a distance the work of hydropower stations and bring automation to other branches, as, for instance, counting articles of production and general accounting, and facilitated intricate astronomic and other computations. It utilises the latest attainments of electronics and telemechanics which practically are no less important than those of nuclear physics.

In speaking of instantaneous action computer mechanisms we should mention the names of Pascal and Academician A. N. Krylov. The first to substantiate the theory of new communication devices was Shannon. But the

greatest honour in this field goes to Norbert Wiener, an American professor of higher mathematics, who won recognition for the new branch of electronics. He defined cybernetics as the study of various communications, information and control realised in different machines (including electronic) and in living organisms, their nervous systems, and human society.

Cybernetics is well developed in the U.S.S.R. Many mathematicians, physicists and designers are working in this field, and today the Soviet Union leads Europe as regards the number and quality of cybernetic machines.

In view of the importance of automation and overall mechanisation for industry and the whole of the national economy, the production of new type of electronic computers is increasing in the U.S.S.R. The general-purpose cybernetic machines operating in the U.S.S.R. include the BESM, capable of doing the work of 300,000 statisticians, and a number of more specialised machines such as the Arrow, the Weather, and others. These units are functioning very successfully at many enterprises, research institutes, clinics, physiological laboratories, etc.

Biology, including physiology, has always depended on the achievements of mechanics in the sphere of precision instruments. Biological models have often inspired inventors of machines. Beginning with Leonardo da Vinci the bird's wing has been used as the model in designing heavier-than-air flying apparatus; the movements of the butterfly larva have been used as the model for tractor caterpillars, etc. All such borrowings are perfectly justifiable historically, for they have enriched science and technology. Mathematician-mechanics and biologists are still designing machines together.

During the past hundred years the physiology of the nervous system has developed no less rapidly than mechanics and physics since the days of Ampère, who was the first to use the term "cybernetics". In addition to the

mechanism of reflexes, physiologists have established the nervous tissue to possess the following characteristics:

1. Specific excitability, ability to respond by excitation or inhibition to very weak stimuli perceived by the sense organs; 2. Preservation of traces of excitation in the brain—the material basis of memory; 3. Coupling of temporary nervous connections between numerous foci of excitation in the higher parts of the brain. The designers of cybernetic machines try to model them after all these properties of the nervous system, utilising the wealth of means of modern electronics. The chief difficulty lay in designing a connection of a *temporary* nature. We can observe such temporary couplings in cybernetic toys—different artificial animals, for instance, the Ashby tortoise, with a number of cathode amplifiers (relays) which enable the toy tortoise to "elaborate reflexes", such as by-passing obstacles, moving towards the light, etc.

It will be noted, however, that the work of the central nervous system of a living organism exhibits a number of regularities lacking in an electronic model. Living tissue, particularly the brain, involves metabolism, which is not encountered in non-living matter. Another very important characteristic of the brain is its ability to change, develop and improve in the process of work, collective life, which certainly is not the case with electronic machines.

Science distinguishes between the specific forms of movement of matter—the functioning of a living organism, of its nervous system—and elementary manifestations of life, to say nothing of machines which are incapable of developing without the assistance of man or of working without programming, although some foreign specialists in cybernetics speak of the ability of procreation in machines and of their forming "robot associations" ("robot" was what the Czech writer Čapek called an automation with functions like those of man, which can substitute human labour in industry and in the home).

Like all automatons, a cybernetic machine has an input relay where information in the form of a programme previously compiled by man is inserted. Instructions on a punched paper ribbon or on a tape commanding the machine in code to add or subtract certain numbers, raise them to a certain power or find their roots, etc., with a certain degree of accuracy, then transmit the solution in the form of electric pulses to a memory unit and store the information for a certain time. This preliminary work partly done by the machine is called *programming*.

An electronic machine has a system of relays that convert the above information into a pattern of electric signals, codes, like a telegraph code, which may be called the machine language. This is also recorded on punched ribbon or a tape (Fig. 37).

All letters of the alphabet and all digits are previously converted into a binary system where each successive "class" exceeds the preceding not tenfold, as in the decimal system, but twofold. In this system, where 2 is taken as the unit, only zero and 1 preserve their accustomed meaning; 2 is a magnitude of a higher order and is expressed by means of 10, 3 is written as 11, 4 as 100, and so on. Thus 13 on a coded tape is written 1101—this is necessary for the subsequent work of the cathode tubes, which serve as computers, switches, and two-hole tape readers with the binary digit 1 meaning a hole punched and 0 meaning no hole punched.

Written instructions are transformed into a series of electric commands, then the information goes to the next register—the *arithmetic* register where different mathematical processes are accomplished with lightning rapidity. This device resembles an arithmometer, but it works on the electronic principle and is connected to the storage unit. The *memory* unit is a truly novel achievement of technology. It is here that cybernetics essentially begins.

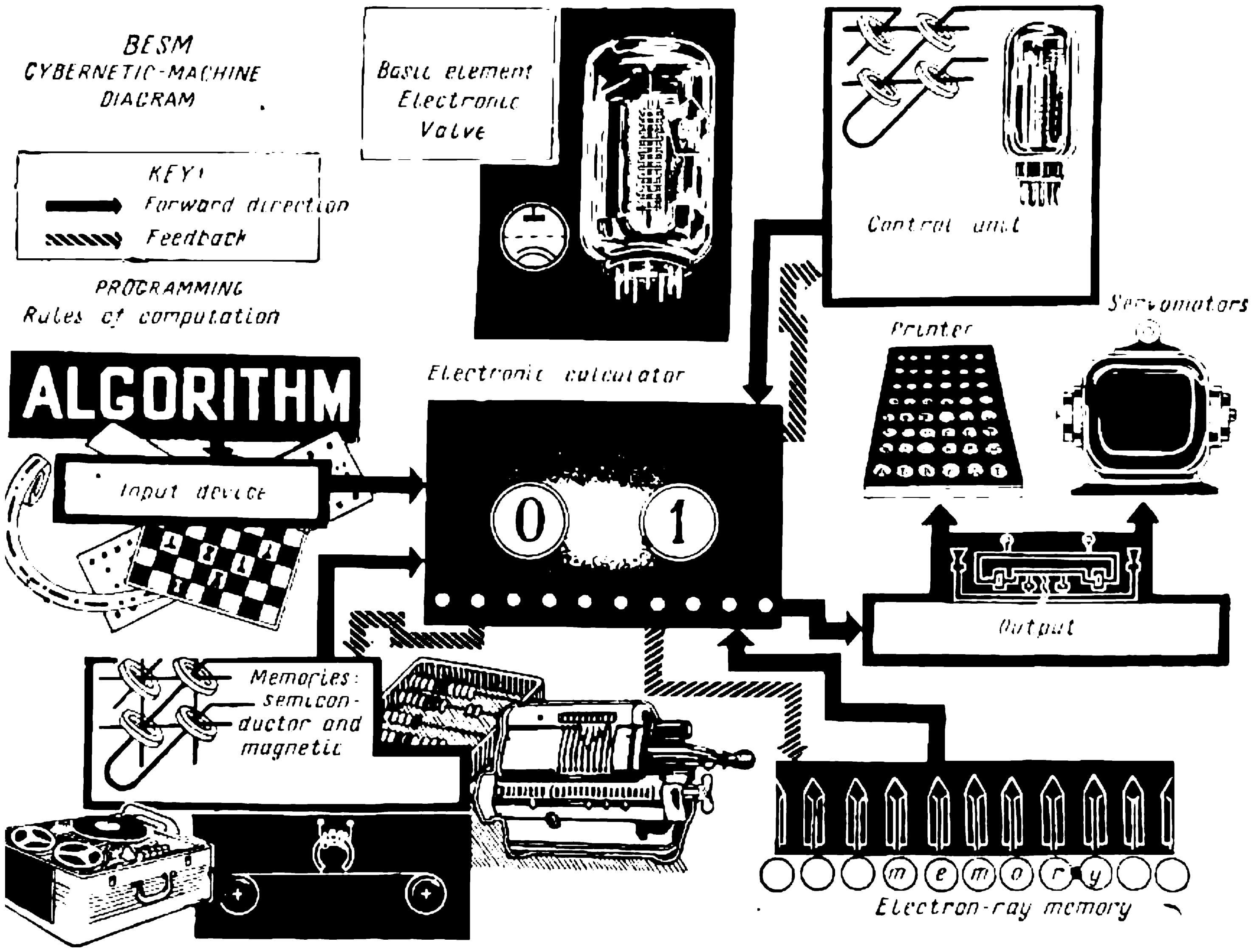


Fig. 37. Diagram of structure and action of general-purpose computing and analytical electronic machine (BESM) capable of performing up to 10,000 mathematical operations per second with numbers expressed by several figures

It, too, is an electronic device which can be likened to a big library with an information department resembling the bibliographic machine we have already described.

The modelling of the mechanism of the gradual formation of temporary electronic connections, retained by the machine's memory, has led some specialists in cybernetics to believe that in this way conditioned reflexes (the temporary nervous connections discovered by Pavlov in the nervous system of living organisms) could be reproduced. What actually occurs here is that some units of the machine let electrical pulses pass with greater ease after re-

petition than in the beginning. But even this is no small achievement in organising and facilitating mental work in which memory is so very important. It is this register that makes possible translation from one language into another, but only of *technical* texts. No fiction can as yet be translated by machine.

Thus, the most important unit of this register—the electronic memory—is a kind of extra-quick inquiry office that can supply information about any operation the machine has ever done. Another part, or form, of the electronic memory is the tape record of all information the machine has to "remember", each piece of information or group of formulas, if we are dealing with mathematics, bearing special markings, "addresses". This part is a few thousandths of a second slower in action than the former, but it contains an infinite number of pieces of information in the form of signs on the tape surface. Moving from one unit to another, the apparatus selects the addresses, just like the signals corresponding to the phone number you need are selected. The work of the electronic memory can also be likened to what you do when you want to find a picture in a thick book: you hold it by the back and thumb through it, suddenly stopping when the required picture catches your eye. In this way cybernetic engineers imitate some of man's elementary mental acts, model his memory, utilising the tremendous velocity of electrons; one of the benefits of this is the rationalisation of the work of translators.

It should be noted here that real human memory is not a storage room. It is an intricate dynamic system associated with metabolism in the brain and exhibiting certain shortcomings, for example, fatigue, as compared with machine memory. To compensate for this, human memory is inexhaustible by its nature and is capable of endless improvement, which cannot be said of the electronic memory that is limited to the programme put in the machine.

Next the *control unit* comes into play. This is a very ingenuous device which makes possible an overall regearing of the machine depending on the results of previous calculations and effects autoregulation of the system; this, too, is accomplished with the very high speed characteristic of electronic machines in general.

What analogy can we find between this process of the machine and the complex reflex acts occurring in the human brain? There are instances in human life when one must limit or change one's reflexes, or habits. In human behaviour there are such limiting factors which Pavlov aptly called conditioned inhibitors. If the action of the electronic mechanism controlling "memory reactions" which we have described makes possible a choice, an analysis corresponding to answering the alternative question of "either—or", the control register corresponds to the solution of a simple logical "if—then" problem. The selective reaction in the machine depends on the results of previously performed acts. Of course by "choice, selection" we mean reactions of a living being with a highly developed nervous system, but the analysis of phenomena coded in numbers can be done without man's participation. That is why such machines are called computing and analytical. What occurs in cybernetic machines is known in technology as "conditioned transition" from one series of consecutive steps to another—a thing not encountered in any other type of machine. To perform its task, a cybernetic device must have, in addition to direct connections, also feedback. Along with electronic memory, this is of prime importance for cybernetics. This idea is borrowed from biology (return afferentation). We emphasised it in dealing with proprioceptive conditioned reflexes and complex technemes underlying the higher labour skills. The control register utilises this physiological phenomenon discovered by Pavlov. Thus, in the general electronic system of a computing and analytical machine working on the principle of analysis and synthesis electric current runs

all the time between the units in both directions. The first stage is transmitting information along what may be called centripetal channels and the second in transmitting commands along centrifugal channels. This resembles to a certain degree what takes place in an active nervous system. The third—and most important stage—is sending signals from acting units when they have performed their operations. Feedback determines the control and automatic regulation of the devices and units. Artificial animals (the Ashby tortoise) also have such devices.

Moreover, some analytical machines have the following devices which ensure complete reliability of functioning of all its parts, like the apparatus for checking telegram texts employed in all major communication offices. To do this, every signal is reproduced in duplicate in the machine, so that the two sets of signals can be checked with one another. Mistakes in such machines are very rare and can be set right immediately; so quickly does the machine correct itself that the engineer at the control panel has no time to notice what was wrong. This is easily understood if we recall that a modern analytical machine performs *10,000 operations* with ten digit numbers per *second,* this speed to be increased in the future.

The machine has an *output relay* which prints the final result of the machine's operations; it "dictates" some other code, switching on or off the servo-motors which turn the rudders of ships, open gates of hydropower stations, etc. These operations are manifested in the work of metal-cutting machines, in steering the course of an ocean-going ship or an aeroplane (the autopilot). Lastly, an electronic machine stops automatically when all operations have been performed and the results verified. All these wonderful technical feats strike the imagination and give rise to unfounded opinions that engineers have created a thinking machine, an electronic brain which is superior to our organ of consciousness, and that consciousness is superfluous. Such and similar terminological errors

are based on underestimation of the essence of the work of the nervous system.

A very important property of cybernetic machines is that the results of operations of one machine can be transmitted as a programme to another machine. This will give rise to automatic lines with a still more intricate process of computation and still greater facilitation of human labour.

This complex interaction of electronic mechanisms takes place in fractions of a second: no sooner is an instruction fed into an electronic machine than the answer is ready. Small wonder that this takes place so fast; it is no less surprising that on a TV screen a ray of light travels several hundred thousand points in 0.04 sec and leaves in our eye the impression of moving objects. Yet we never call a TV set a thinking machine since we know who invented it and when and where it was invented.

A study of a computing machine shows that there must be a special relay for each step of its work: input, computer, memory and control units, follow up system, output, etc. But in the brain of man or an animal all these functions (coupling, reproduction, control of performance, etc.) are performed, as has been demonstrated in the laboratories of Pavlov and his school, by nerve cells of microscopic dimensions (a few thousandths of a millimetre). It is doubtful that such magnitudes will ever be accomplished in cybernetics, although the designers must and will strive for this by availing themselves of the possibilities for economising space afforded by semiconductors.

We have already said that, imitating in part the reflex mechanism of the brain, but working faultlessly and without loss of time, electronic computing and analytical machines can do the work of numerous calculators and, consequently, help to rationalise work. However, qualities characteristic of the brain's functions—consciousness—must not be ascribed to powerful modern mathematical machines. It is equally useless to build them in the human

shape although their actions may resemble those of human beings.

In recent years cybernetic machines have become infinitely varied in type, immeasurably more perfect and fast. Technical literature contains descriptions of electronic machines which themselves compile the programme of action, although the methods of such machine programming are predetermined by men—highly qualified mathematicians and engineers just the same.

The development of cybernetics is particularly important under conditions of communist construction in the U.S.S.R., where facilitation of human labour constitutes problem number one. Cybernetics will free tens of thousands of calculators from hard mental work, just as the introduction of programme machinery is freeing workers from heavy physical labour. We may note here that operating complex automatic devices requires a higher educational level of workers, so that greater automation, including the use of cybernetic machines, will further efface the boundaries which divide mental work from physical.

Capitalists in bourgeois countries would like to use "thinking mechanisms" instead of workers, thus doing away with the class struggle. Some people have found the time to calculate that with cybernetics in wide use, 30,000,000 workers in the U.S.A. will lose their jobs within 10 years. This is nothing to be happy about. It is clear, however, that the idea to substitute machines for the initiative and consciousness of the working people is senseless. And not every advocate of the bourgeois system would attempt to toy with the idea even as a fancy.

While acknowledging the great future in store for cybernetics and its value for the technical aspect of physical and mental work, even taking into account that the electronic machine may help physiologists to gain a deeper insight into the simplest of the brain's functions, we emphasise that the brain is not an electronic machine and that the latter will never become a brain, will never be

the material substrate of social consciousness. The construction of complex computing and analytical machines, automatic lines and units, automatic shops and whole factories provides extra proof of the Marxist-Leninist teaching on the unlimited prospects for the development of society and the historical regularities in the development of the brain's functions mentioned earlier.

Today there is an electronic machine that reads aloud printed texts to the blind and a multitude of other machines capable of substituting for our sense organs.

Cybernetics finds application in medicine as well: there are machines which automatically supply anaesthetics during surgical operations, measure gas exchange during exercise, count white and red corpuscles, decode electrocardiograms, analyse the state of biocurrents in the brain, etc.

Can Machinery Completely Supersede the Human Brain?

Let us compare the structural and functional principles of modern electronic computing and analytical machines with the processes taking place in the head of a man solving a mathematical problem. The central nervous system of animals and man is the most complex product of animate nature. It came into being and has developed in the process of evolution; it consists of numerous (several billion) nerve cells and conducting fibres and performs its functions jointly with the sensitive receptors of stimuli (sense organs) and various effectors (muscles and glands). The brain of man and higher animals is abundantly supplied with blood and through metabolism maintains chemical and nervous connections with other internal organs of the body. It depends on the latter but at the same time controls and regulates their functions.

The chief, most characteristic property of the central nervous system and its highest part—the brain—is its ability, on the basis of a comparatively small number of

inborn connections, unconditioned reflexes (food, defensive, sex and other instincts), to form in the course of individual life an unlimited number of temporary connections, conditioned reflexes, which in the end give rise to habits, a series of complex athletic or working skills. Machines, on the other hand, receive a lot of instructive material in the form of programmes and combine these data with extreme precision and speed. And yet, the high *quantitative* results obtained in such machines do not form a new *quality*—do not engender consciousness. Some hold that the programme put into the electronic machine corresponds to unconditioned reflex in man. This, however, is an unsubstantiated statement: a programme compiled for any individual task cannot by any means be regarded as inborn, neither can we speak of acquiring habits in regard to the memory register.

Some foreign specialists in cybernetics who consider the activity of the brain from an idealist standpoint assert that, with the aid of semiconductors and other materials, connections can be formed in machines without programming. Even if this were ever accomplished, such a machine would still be a product of human thought, of human labour. The most important principle of human cerebral activity (we are speaking only of the human brain) has always been a system of temporary conditioned connections developing in the process of social labour and constituting the material basis of the human mind.

We have spoken of the higher, second, signal system in the brain, superimposed on the first. It is only this superstructure that makes possible abstract thinking, forming and generalising concepts in the process of human intercourse.

Designers of cybernetic machines who would substitute by machinery the work of the brain of such men as Newton or Lobachevsky are sadly mistaken, for a machine will never be able to create any abstract concepts or creative ideas connected with them. It is, and will ever be, no more

than an executive apparatus, a subsidiary, albeit an important means of organising mental work.

It is said that a cybernetic device can nevertheless make certain generalisations, judgements and deductions. This is not true. "Generalisation", i.e., the diffusion of physical processes can also be observed in technology—the appearance of light haloes on a photographic plate. But the generalisation of signals of the first and particularly second signal systems in the human brain is selective, creative. It does not reveal all, but only the most essential, causal connections between the phenomena of the surrounding world. Generalisation is attained by means of the word, spoken or written, or the language of mathematics—formulas which generalise an extensive class of definite phenomena and are used in the construction of cybernetic devices.

All the specific processes operating in the human brain, together with the decisive factors of historical development of society, underlie the appearance of science and technology whose attainments enable modern cybernetic experts to construct their wonderful and most useful machines.

The origin of any machine lies in work; cybernetics, too, was born in work and in order to make work easier; it could not come into being of itself. The word, so essential for collective life, also arose in the process of work. And although they facilitate and supersede human labour (both physical and mental) and can be interconnected in their work, thus running shops or even whole factories, cybernetic machines do not create any new forms of production relations.